Lecture 2

Sensor Technologies

Part 2

Sensors

Topics

- Sensor layer
  - Identification technologies
    - QR code, RFID, NFC
  - Sensors
    - Temperature, humidity, brightness, vibration, pressure, speed, ...

工作原理 & 輸出介面

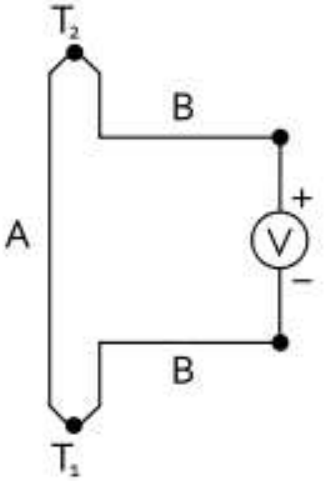
溫度感測器

- 常見溫度感測器
  - 熱敏電阻(Thermistor)
    - PTC (正溫度係數)
    - NTC (負溫度係數)
  - 熱電偶(Thermocouple)
    - Type K, Type J, Type N, …
  - 感溫積體電路
  - …

NTC

PTC

- **席貝克效應** (Seebeck Effect, 1821)
  - 將二種不同金屬各自的二端分別連接
  - 若兩端點有溫度差，會產生電動勢



1770~1831

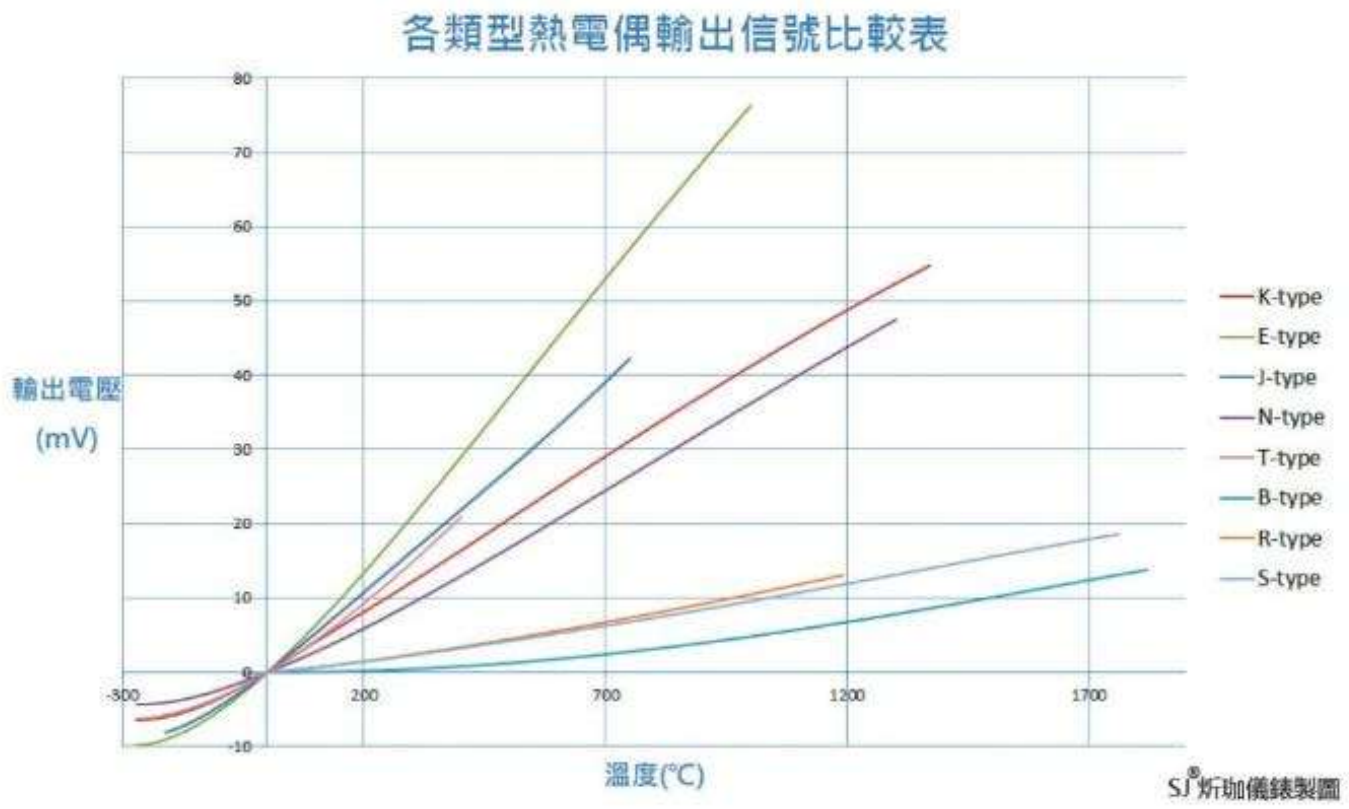
Seebeck Effect

ChatGPT

The Seebeck effect, named after the German physicist Thomas Johann Seebeck who discovered it in 1821, refers to the phenomenon where a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between them. In simpler terms, when you have a loop made of two different metals and there's a temperature difference at the junctions, it generates an electric current.

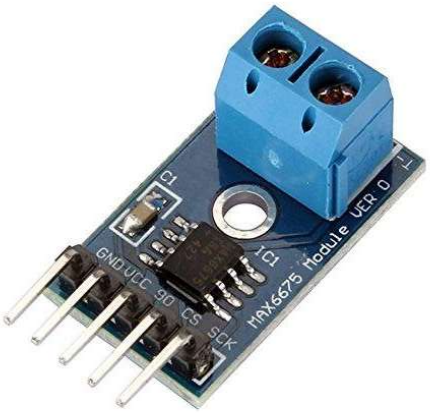
The Seebeck effect is the underlying principle behind thermocouples, which are widely used for temperature measurement in various industrial and scientific applications. These devices utilize the voltage generated by the Seebeck effect to measure temperature differentials.

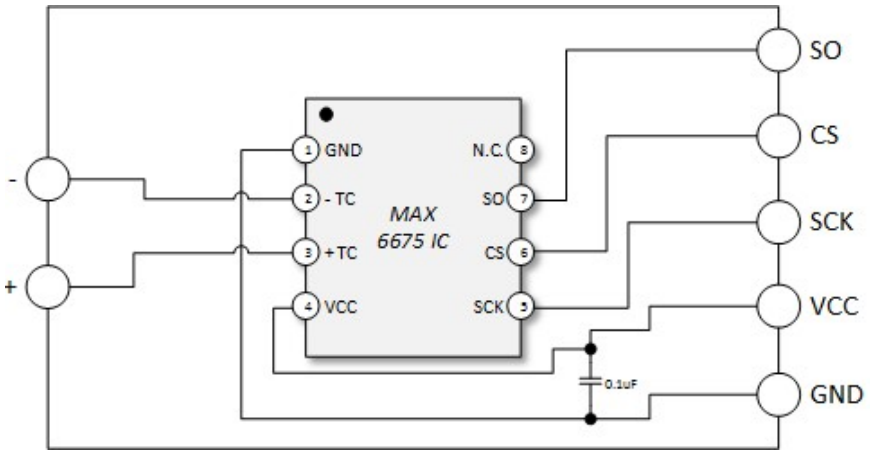
- 常見的**熱電偶**種類
  - K-type (鎳鉻合金或鎳鋁合金)
    - 最廣為使用的熱電偶型式
    - 可量測範圍：−200°C ~ +1000 °C
  - N-type (鎳鉻矽合金或鎳矽合金)
    - 高穩定性及高溫抗氧化性，常應用在高溫測量
    - 可量測範圍：−200°C ~ +1200 °C
  - T-type (銅或銅鎳合金)
    - 適用於低溫量測
    - 可量測範圍：−250°C ~ +350 °C



https://www.sj-gauge.com/_tw/faq/detail.php?cid=15&faqid=167

Thermocouple





K-type Module MAX6675

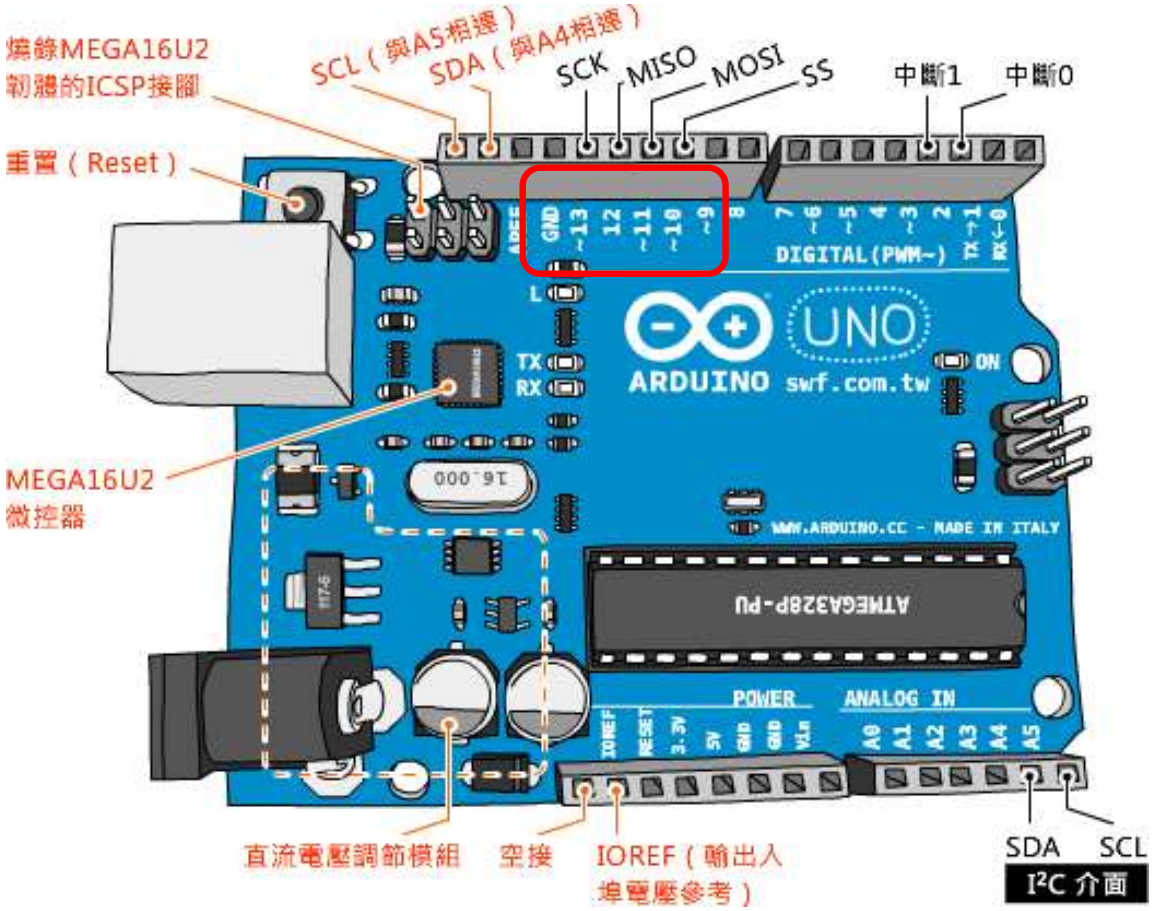
Feature:

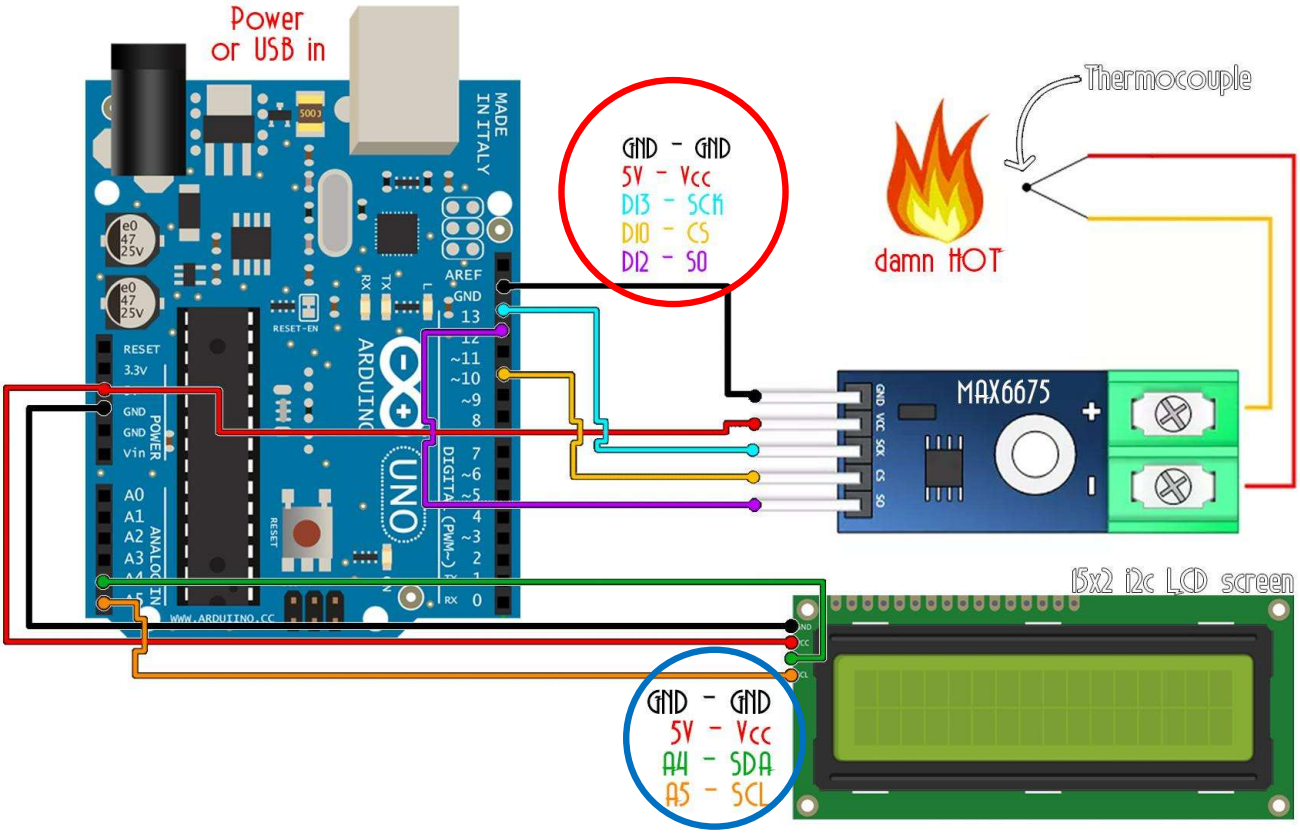
- Supply voltage: 3.3 ~ 5V
- Range: 0 ~ 1024℃
- Resolution: ±0.25℃
- Output: SPI

http://henrysbench.capnfatz.com/henrys-bench/arduino-temperature-measurements/max6675-temp-module-arduino-manual-and-tutorial/

- **濕度感測**
  - 電阻式
    - 用濕敏材料吸收空氣中的水分而導致本身電阻值發生變化
    - 半導體陶瓷濕敏元件、氯化鋰濕敏電阻、有機高分子膜濕敏電阻
  - 電容式
    - 如高分子濕度濕敏電容器，此類濕敏元件的介電常數隨濕度而變化

https://kknews.cc/science/xveqv4r.html


燒錄MEGA16U2
韌體的ICSP接腳
SCL（與A5相選）
SDA（與A4相選）
SCK
MISO
MOSI
SS
中斷1
中斷0
重置（Reset）
MEGA16U2
微控器
DIGITAL(PWM~)
UNO
ARDUINO
swf.com.tw
ON
TX
RX
WWW.ARDUINO.CC - MADE IN ITALY
ATMEGA328P-PU
POWER
ANALOG IN
直流電壓調節模組
空接
IOREF（輸出入
埠電壓參考）
SDA
SCL
I²C 介面

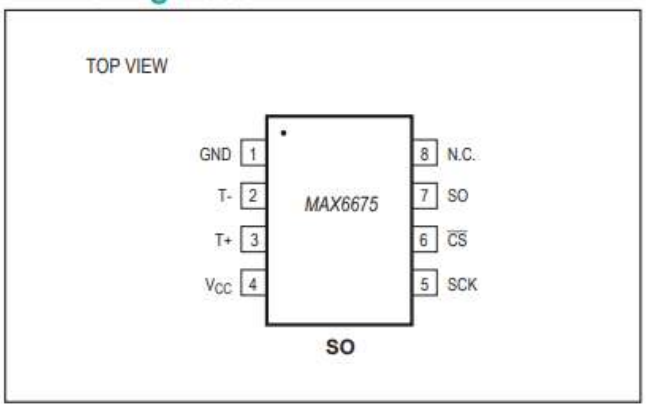

Power
or USB in
GND - GND
5V - Vcc
D13 - SCK
D10 - CS
D12 - SO
Thermocouple
damn HOT
MAX6675
16x2 i2c LCD screen
GND - GND
5V - Vcc
A4 - SDA
A5 - SCL

EVALUATION KIT AVAILABLE

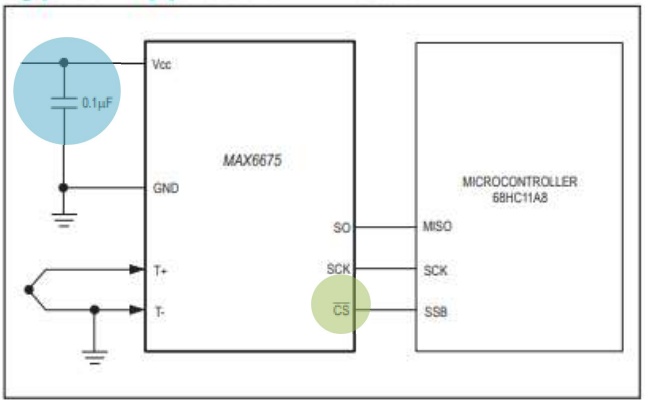
Click here to ask about the production status of specific part numbers.

MAX6675 — **Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)**

Pin Configuration

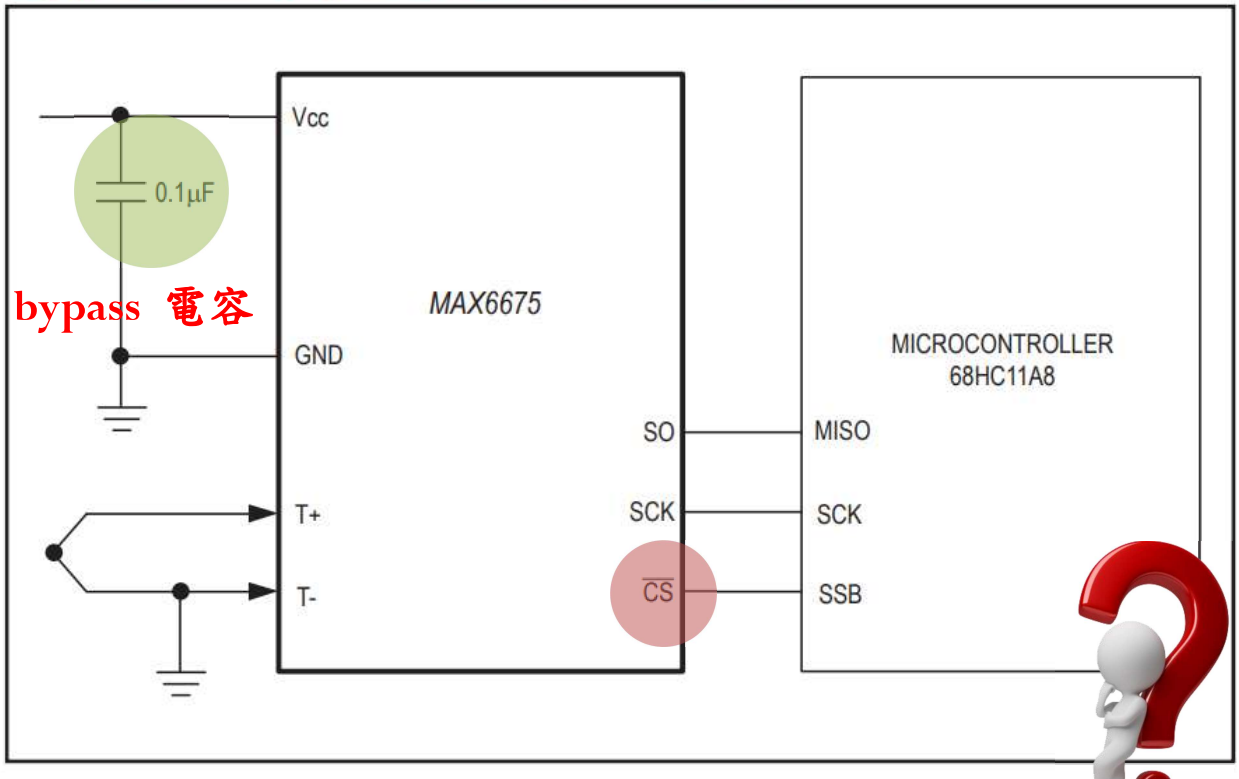


Typical Application Circuit

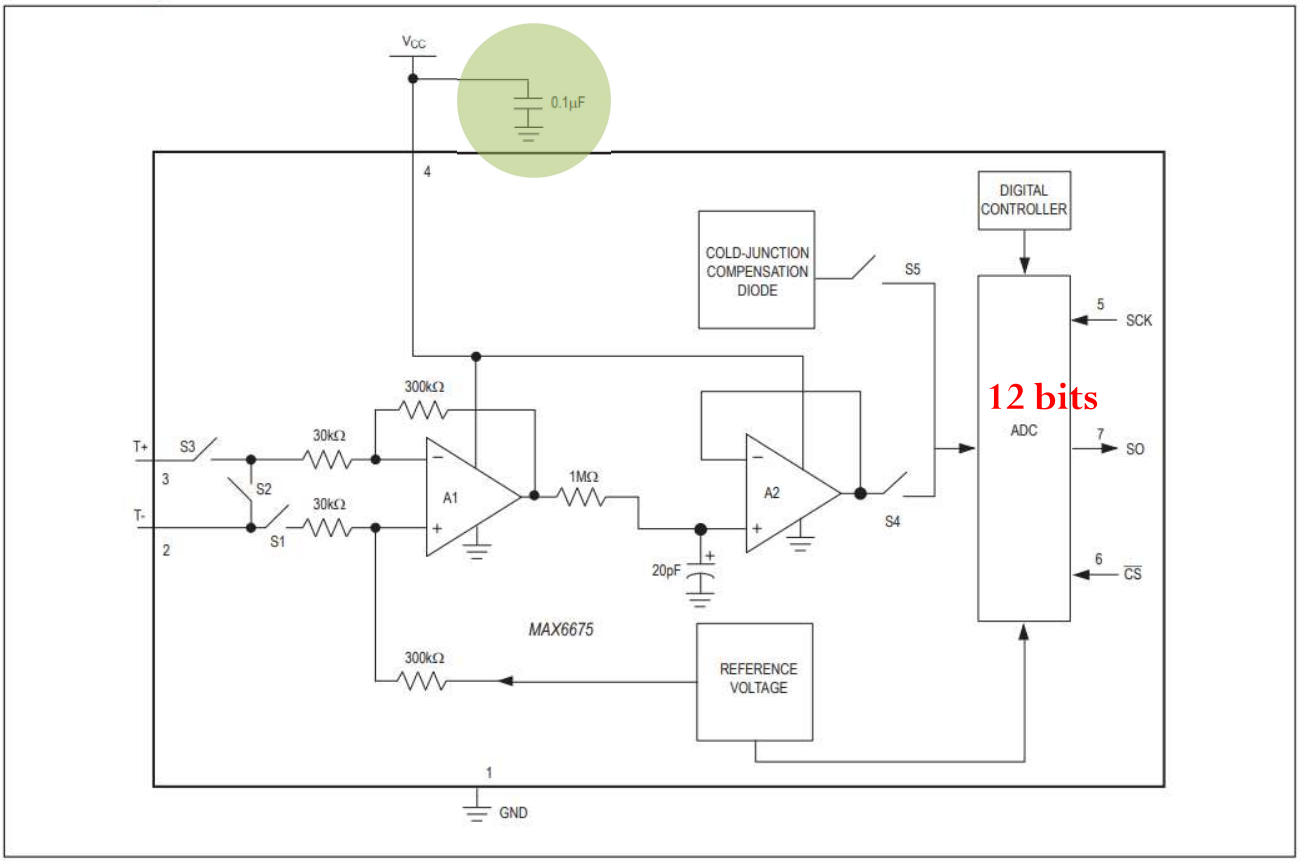


https://www.analog.com/media/en/technical-documentation/data-sheets/MAX6675.pdf

Typical Application Circuit



Block Diagram



Electrical Characteristics

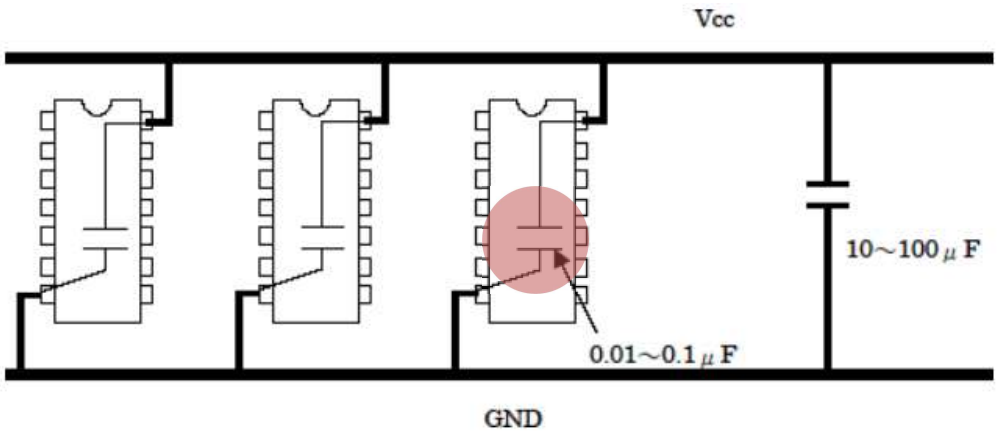
(V_{CC} = +3.0V to +5.5V, T_A = -20°C to +85°C, unless otherwise noted. Typical values specified at +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Error		$T_{THERMOCOUPLE}$ = +700°C, T_A = +25°C (Note 2)	V_{CC} = +3.3V	-5		+5	LSB
			V_{CC} = +5V	-6		+6	
		$T_{THERMOCOUPLE}$ = 0°C to +700°C, T_A = +25°C (Note 2)	V_{CC} = +3.3V	-8		+8	
			V_{CC} = +5V	-9		+9	
		$T_{THERMOCOUPLE}$ = +700°C to +1000°C, T_A = +25°C (Note 2)	V_{CC} = +3.3V	-17		+17	
			V_{CC} = +5V	-19		+19	
Thermocouple Conversion Constant					10.25		µV/LSB
Cold-Junction Compensation Error		T_A = -20°C to +85°C (Note 2)	V_{CC} = +3.3V	-3.0		+3.0	°C
			V_{CC} = +5V	-3.0		+3.0	
Resolution					0.25		°C
Thermocouple Input Impedance					60		kΩ
Supply Voltage	V_{CC}			3.0		5.5	V
Supply Current	I_{CC}				0.7	1.5	mA
Power-On Reset Threshold		V_{CC} rising		1	2	2.5	V
Power-On Reset Hysteresis					50		mV
Conversion Time		(Note 2)			0.17	0.22	s
SERIAL INTERFACE							
Input Low Voltage	V_{IL}					0.3 x V_{CC}	V
Input High Voltage	V_{IH}			0.7 x V_{CC}			V
Input Leakage Current	I_{LEAK}	V_{IN} = GND or V_{CC}				±5	µA
Input Capacitance	C_{IN}				5		pF

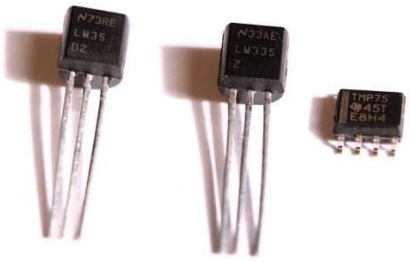
Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2	T-	Alumel Lead of Type-K Thermocouple. Should be connected to ground externally.
3	T+	Chromel Lead of Type-K Thermocouple
4	V_{CC}	Positive Supply. Bypass with a 0.1µF capacitor to GND.
5	SCK	Serial Clock Input
6	$\overline{CS}$	Chip Select. Set $\overline{CS}$ low to enable the serial interface.
7	SO	Serial Data Output
8	N.C.	No Connection

- Decoupling capacitor → filter

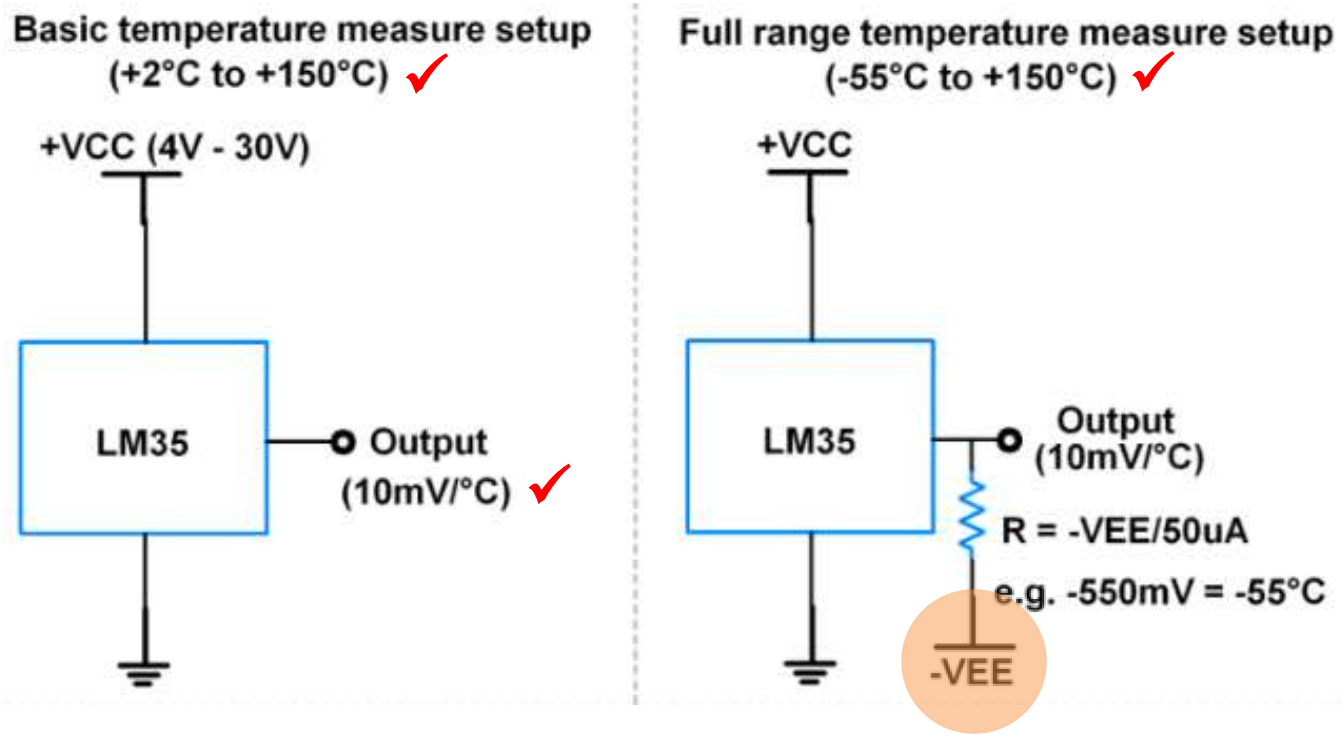


https://toshiba.semicon-storage.com/tw/semiconductor/knowledge/faq/logic_common/logic_common_06.html

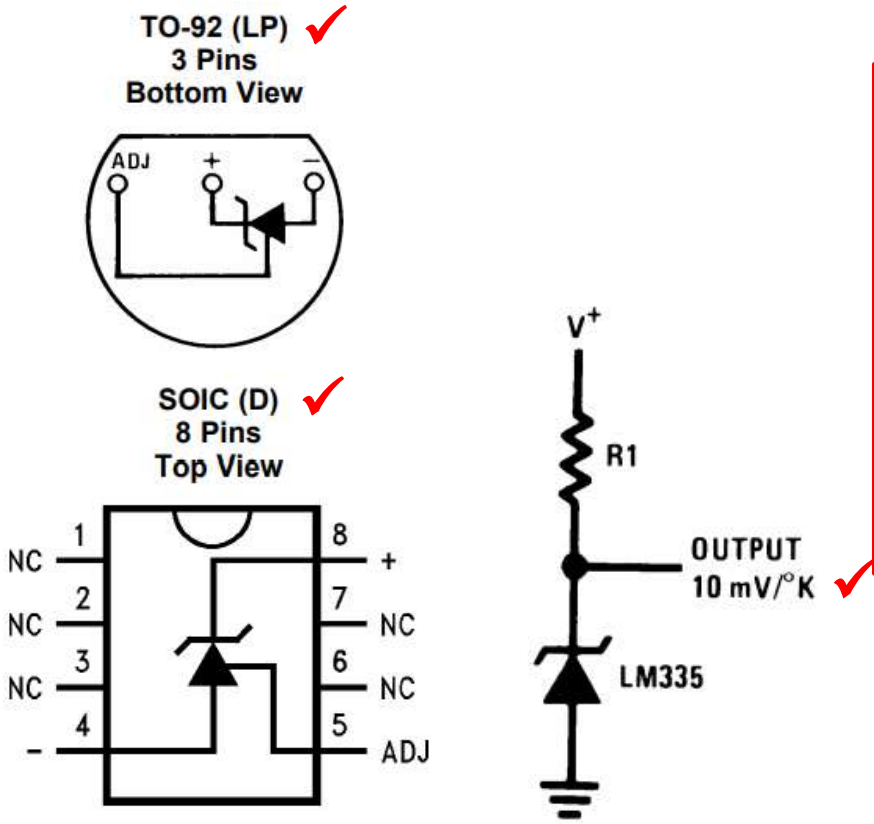


- 溫度感測器
  - 產品有多種型態
    - 膨脹變化型、顏色變化型、電阻變化型、電流變化型、電壓變化型、頻率變化型 …
  - 常見的電壓變化型溫度感測器
    - LM35：輸出電壓與**攝氏**溫度呈線性關係
    - LM335：輸出電壓與**凱氏**溫度呈線性關係

$$°K = ℃ + 273.15$$



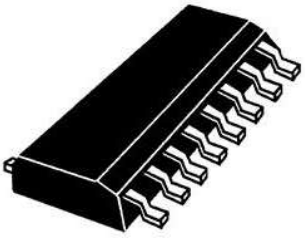
http://manintheit.org/embedded/interfacing-lm35-with-atmega328p/



半導體封裝型式

- **TO-92**
- **TO-xxx**
- **SOIC**
- **DIP**
- **…**

LM x35



- SOIC (小外型集成電路封裝)
  - – Small Outline Integrated Circuit Package

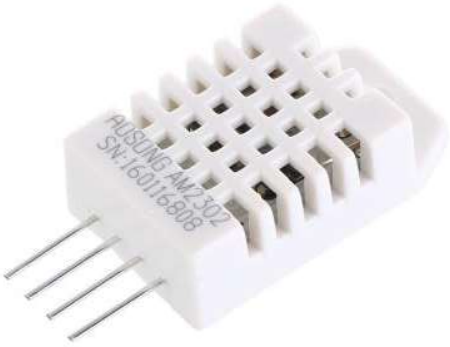
- DIP (雙列直插封裝)
  - – Dual In-line Package
- TO (電晶體外型封裝)
  - – Transistor Outline Package

		MIN	NOM	MAX	UNIT
LM135, LM135A	Continuous ($T_{MIN} \le T_A \le T_{MAX}$)	−55		150	°C
	Intermittent (1)	150		200	
LM235, LM235A	Continuous ($T_{MIN} \le T_A \le T_{MAX}$)	−40		125	°C
	Intermittent (1)	125		150	
LM335, LM335A	Continuous ($T_{MIN} \le T_A \le T_{MAX}$)	−40		100	°C
	Intermittent (1)	100		125	

LM x35 溫度量測範圍

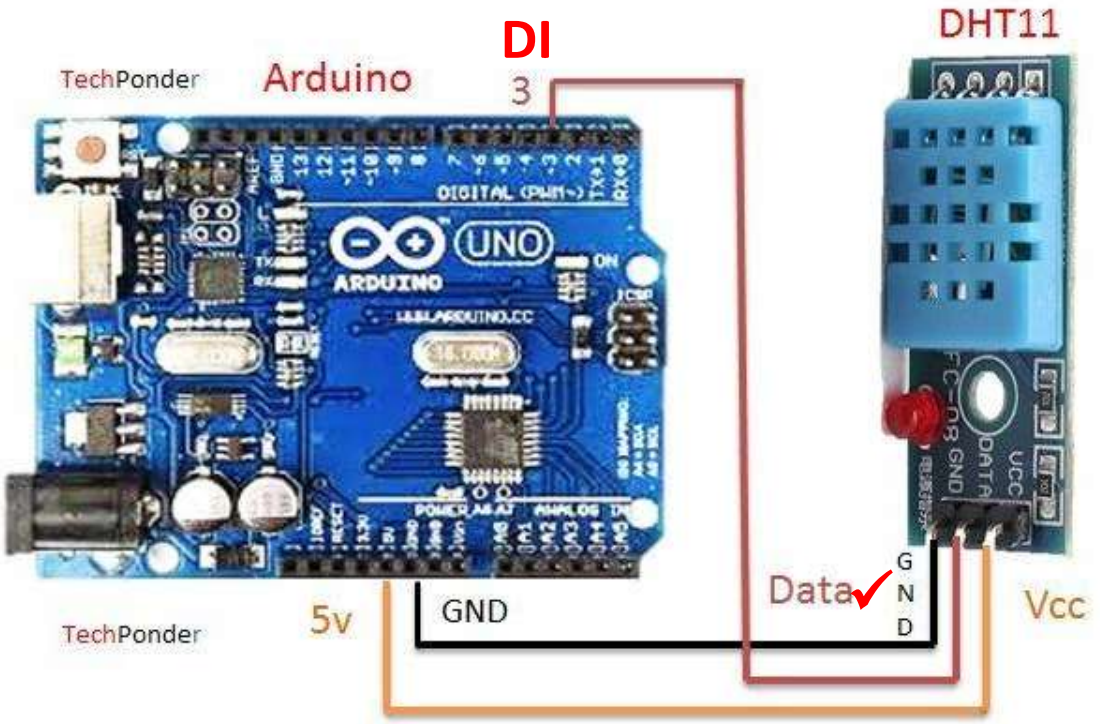
- 溫溼度感測器
  - DTH11
    - 0 ~ 50°C；±2°C accuracy
  - DTH12
    - -20 ~ 60°C； ±0.5°C accuracy
  - DTH22
    - -40 ~ 80°C；±0.5°C accuracy

DTH11



DTH22

https://learn.adafruit.com/dht/overview



Humidty / Temparature (DHT11) Sensor interfacing to Arduino

常見串列傳輸介面

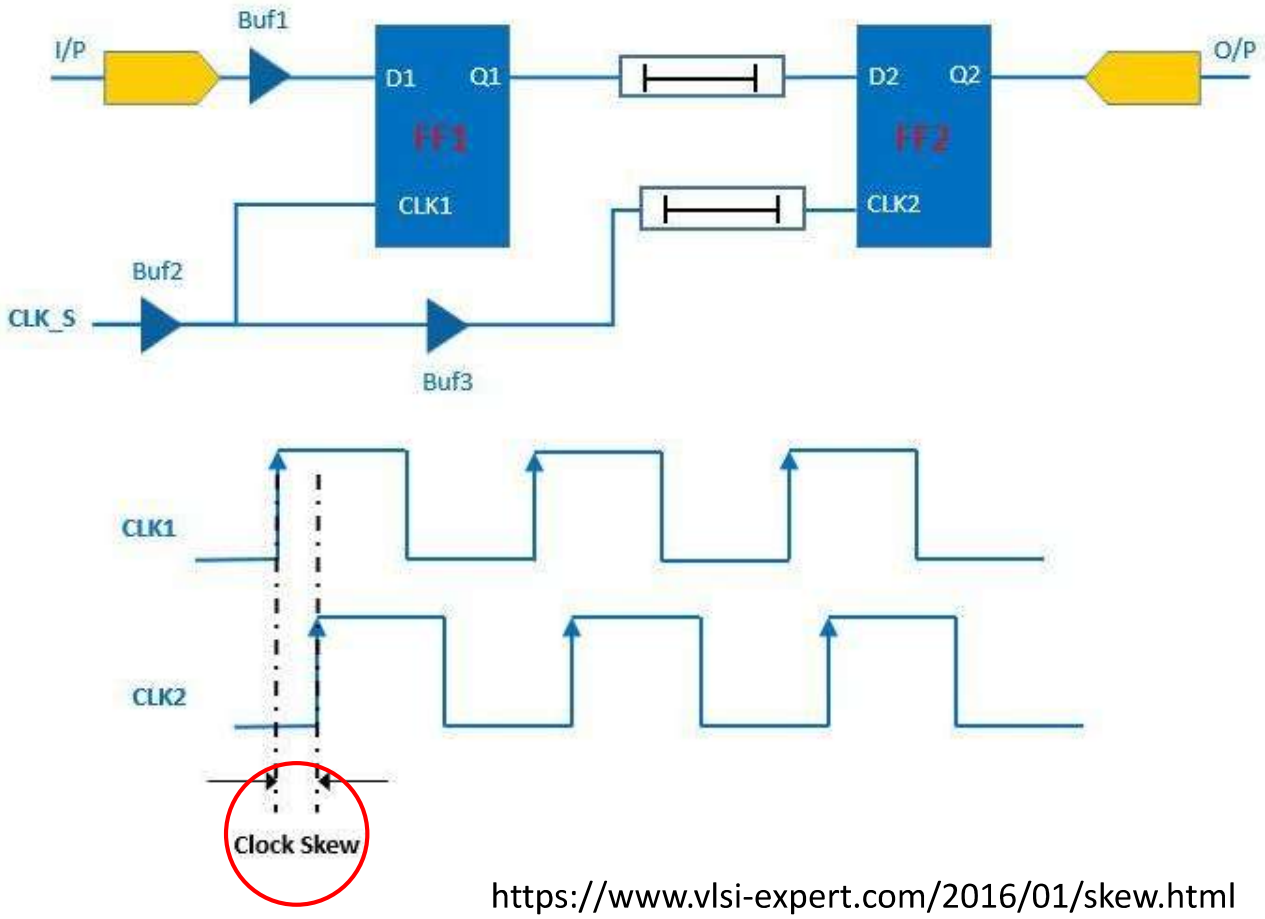
串列介面	格式	裝置數量 (最大值)	距離 (最大值，呎)	速率 (最大值，bps)
RS-232	非同步	2	50~100	20k
RS-422	非同步	10	4000	10M
RS-485	非同步	32	4000	10M
I^2C	同步	40	18	3.4M
SPI	同步	8	10	2.1M
Microwire	同步	8	10	2M
1-Wire	非同步	由電容與速率而定	1000	16k
USB	非同步	127	16(可透過 5 個集線器擴充到 96 呎)	1.5M、12M、480M

https://www.epcio.com.tw/paper/應用非同步傳輸原理在遠端輸出入之控制.pdf

- **並列 vs 串列**
  - **並列**傳輸時脈提升較困難，若要提高傳輸效能，就需要增加並列介面的資料寬度，相對的會增加線路成本、電路板面積、改變擴充槽等
    - 印表機埠
  - **串列**傳輸可以擺脫同步時脈的運作方式，在不增加接腳、不改變電路板、不增加製造成本之下，就只須致力時脈的提升
    - I2C、SPI、UART、USB、…

- **單工、半雙工、全雙工**
  - **單工**：只支持信號在一個方向上傳輸，任何時候不能改變信號的傳輸方向
    - 廣播
  - **半雙工**：允許信號在兩個方向上傳輸，但某一時刻只允許信號在一個信道上單向傳輸
    - 例如：I2C
  - **全雙工**：允許同時進行雙向傳輸
    - 例如：SPI、UART

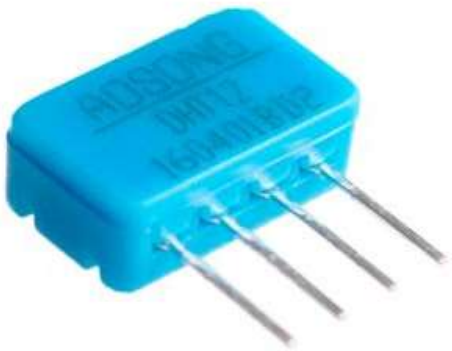
- **同步 vs 非同步**
  - 同步需額外提供時脈訊號，使兩端機器溝通時能夠藉此同步收發資料。
  - 同步傳輸不需要start/stop bit，因此能夠一次傳較多的資料。
  - 同步傳輸需要解決時鐘偏移對資料傳輸造成的影響。
    - 時鐘偏移(clock skew)：時脈訊號到達數位電路各個部分所用時間的差異，這是由於時脈訊號到各個電子元件的所經路徑長度不同而產生。

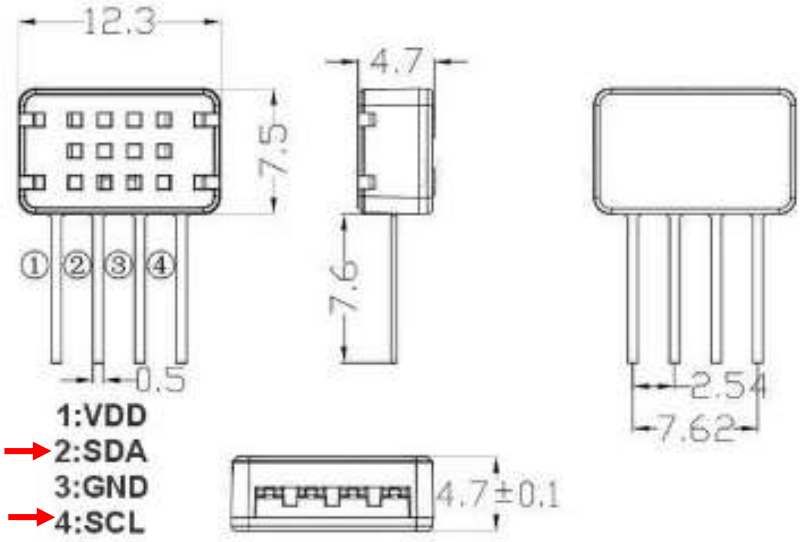


https://www.vlsi-expert.com/2016/01/skew.html

	I2C	SPI	UART
資料傳輸	串列	串列	串列
傳輸方向	半雙工	雙工	雙工
時脈	同步	同步	非同步

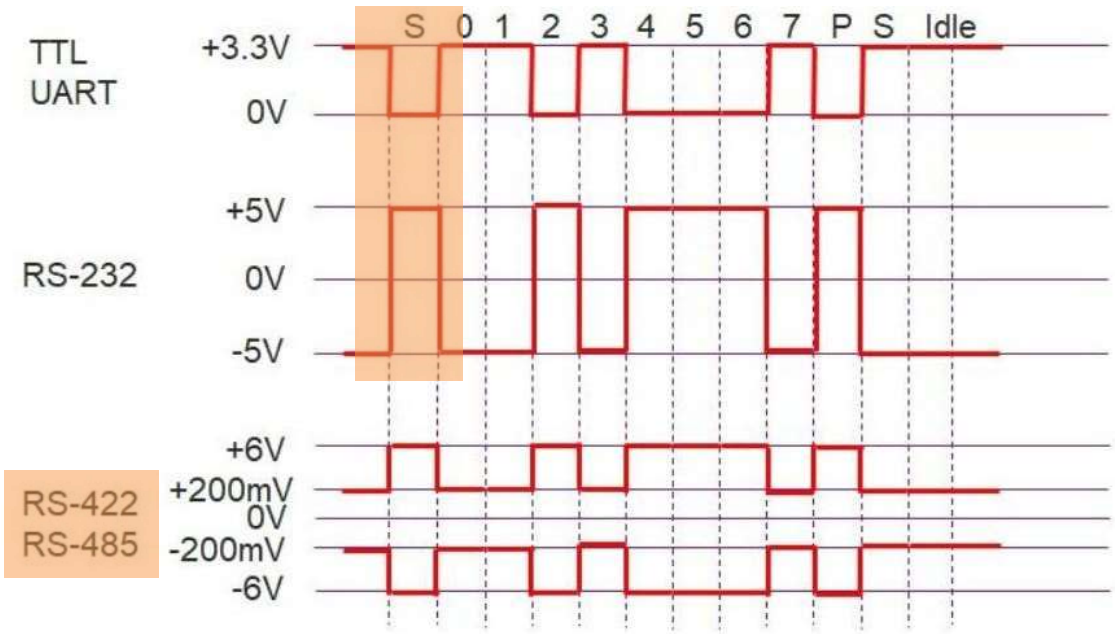
DHT12





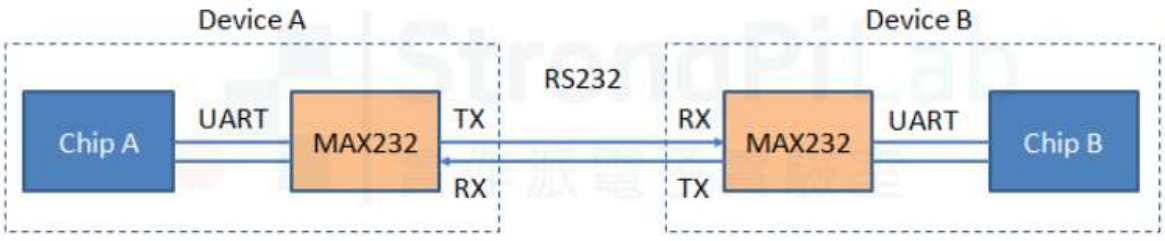
輸出介面？

- **UART, RS232, RS422, RS485**



https://www2.macnica.com/apac/galaxy/zh_tw/products-support/technical-articles/talking-about-the-technical-application-of-usb-interface-conversion/

- **UART, RS-232**
  - UART正邏輯、RS-232負邏輯
  - 電壓位準？



UART 與 RS232 的接線方塊圖

https://www.strongpilab.com/rs232-uart-difference/

TEXAS INSTRUMENTS

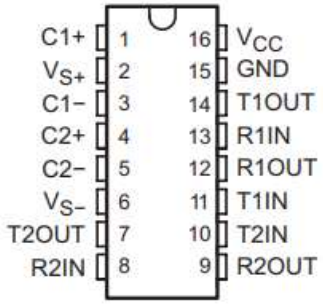
MAX232x Dual EIA-232 Drivers/Receivers

Pin Functions

PIN NAME	PIN NO.	TYPE	DESCRIPTION
C1+	1	—	Positive lead of C1 capacitor
VS+	2	O	Positive charge pump output for storage capacitor only
C1-	3	—	Negative lead of C1 capacitor
C2+	4	—	Positive lead of C2 capacitor
C2-	5	—	Negative lead of C2 capacitor
VS-	6	O	Negative charge pump output for storage capacitor only
T2OUT, T1OUT	7, 14	O	RS232 line data output (to remote RS232 system)
R2IN, R1IN	8, 13	I	RS232 line data input (from remote RS232 system)
R2OUT, R1OUT	9, 12	O	Logic data output (to UART)
T2IN, T1IN	10, 11	I	Logic data input (from UART)
GND	15	—	Ground
V_{CC}	16	—	Supply Voltage, Connect to external 5V power supply

Top View

MAX232 . . . D, DW, N, OR NS PACKAGE
MAX232I . . . D, DW, OR N PACKAGE
(TOP VIEW)



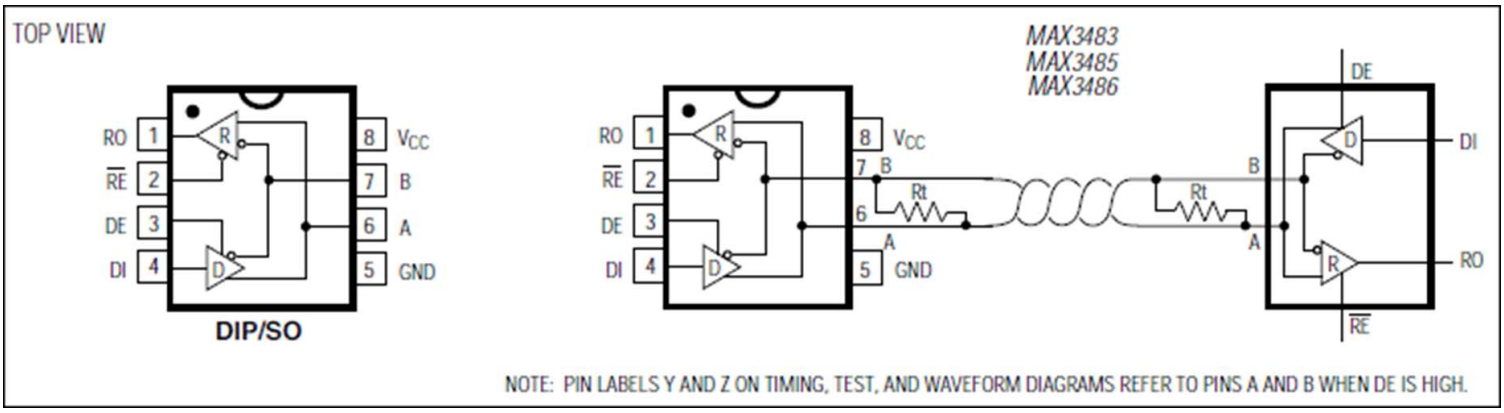
https://www.ti.com/lit/ds/symlink/max232.pdf

- **UART, RS-485**

Click here for production status of specific part numbers.

MAX3483/MAX3485/ MAX3486/MAX3488/ MAX3490/MAX3491

3.3V-Powered, 10Mbps and Slew-Rate-Limited True RS-485/RS-422 Transceivers



https://www.analog.com/en/products/max3485.html#product-reference

https://www.analog.com/media/en/technical-documentation/data-sheets/MAX3483-MAX3491.pdf

Pin Description

PIN			NAME	FUNCTION
MAX3483/ MAX3485/ MAX3486	MAX3488/ MAX3490	MAX3491		
1	2	2	RO	Receiver Output. If A > B by 200mV, RO will be high; if A < B by 200mV, RO will be low.
2	—	3	$\overline{RE}$	Receiver Output Enable. RO is enabled when $\overline{RE}$ is low; RO is high impedance when $\overline{RE}$ is high. If $\overline{RE}$ is high and DE is low, the device will enter a low-power shutdown mode.
3	—	4	DE	Driver Output Enable. The driver outputs are enabled by bringing DE high. They are high impedance when DE is low. If $\overline{RE}$ is high and DE is low, the device will enter a low-power shutdown mode. If the driver outputs are enabled, the parts function as line drivers. While they are high impedance, they function as line receivers if $\overline{RE}$ is low.
4	3	5	DI	Driver Input. A low on DI forces output Y low and output Z high. Similarly, a high on DI forces output Y high and output Z low.
5	4	6, 7	GND	Ground
—	5	9	Y	Noninverting Driver Output
—	6	10	Z	Inverting Driver Output
6	—	—	A	Noninverting Receiver Input and Noninverting Driver Output
—	8	12	A	Noninverting Receiver Input
7	—	—	B	Inverting Receiver Input and Inverting Driver Output
—	7	11	B	Inverting Receiver Input
8	1	13, 14	V_{CC}	Positive Supply: 3.0V ≤ V_{CC} ≤ 3.6V
—	—	1, 8	N.C.	No Connect—not internally connected

- **Serial interface**
  - UART
- **Communication standard**
  - RS-232
  - RS-422
  - RS-485

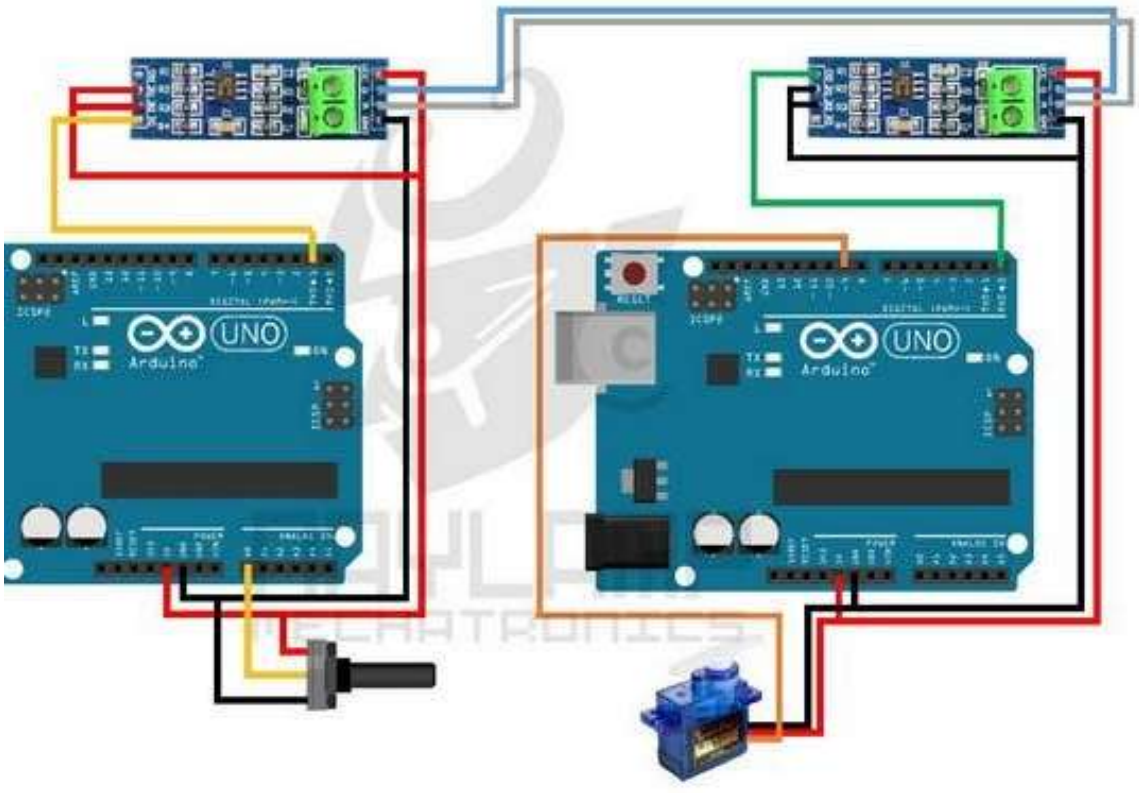
- **RS-232**
  - Full-duplex, 1:1
  - 信號電位值較高，易損壞介面電路的晶片
  - 傳輸速率較低
  - 共地傳輸容易產生共模干擾
  - 傳輸距離有限

https://twgreatdaily.com/KP-wCW4BMH2_cNUgf8Z6.html

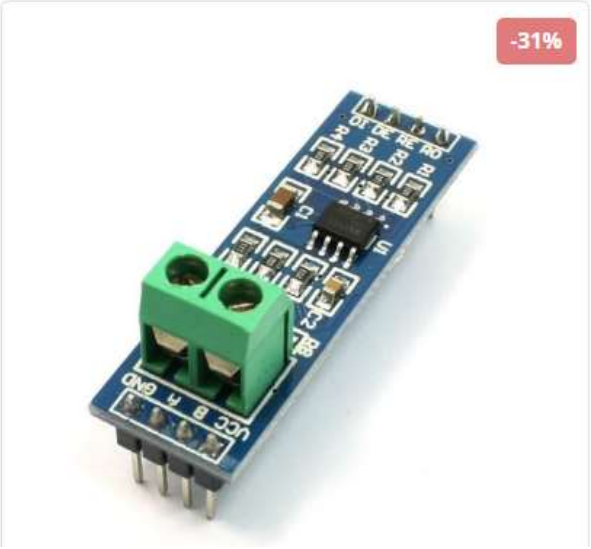
- **RS-485**
  - Full- or Half-duplex (primary), m:n
  - 差分傳輸方式
  - 信號電位值降低；
    - 邏輯「1」：兩線間的電壓差+2V~+6V
    - 邏輯「0」：兩線間的電壓差-6V~-2V
  - 數據最高傳輸速率：10Mbps
  - 抗共模干擾能力強
  - 最大傳輸距離標準值4000英尺

- **RS-422**
  - Full-duplex, 1:n
  - 差分傳輸方式
  - 兩對雙絞線：全雙工收發
  - 電氣性能與RS-485完全一樣
  - 最大傳輸距離：4000英尺
  - 最大傳輸速率：10Mb/s

- **Arduino, RS-485**



TTL 轉 RS485/RS422 模組 MAX485 Arduino 可用



https://www.taiwaniot.com.tw/product/ttl-to-rs485rs422-max485-module/

Homework

- 說明UART, RS-232, RS-422, RS-485特性及異同。
  - 運用文字、圖表或示意圖
  - **註明參考資料出處**
  - 一張A4為限

- 請自己找資料，千萬不要抄襲同學的答案！
- 建議答案儘量結構化，易讀、易了解內涵
- 內容以一張A4為限，字體：12號字/標楷/Times New Roman
- 請助教挑選最優的10位同學答案，分享給所有同學參考。

氣體感測器

- 氣體感測器
  - 將空氣中特定的氣體濃度轉換成電壓、電流或電阻值
- 類型
  - 半導體式
    - 應用廣泛、成本低；穩定性差
  - 電化學式
    - 靈敏度高、線性度佳；價格高
  - 觸媒燃燒式
    - 反應速度快、檢測準確；是放毒氣、有爆炸危險

MQ2

MQ3

MQ-3: 乙醇

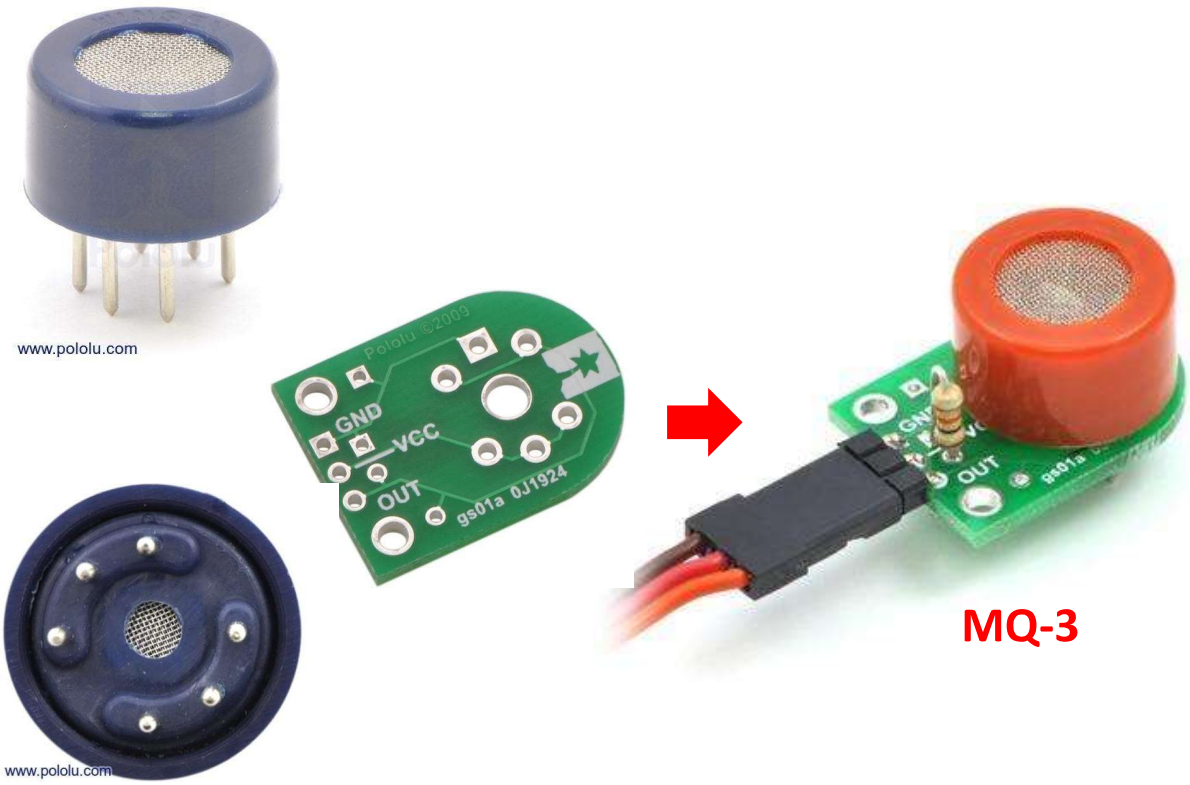
MQ-7: 一氧化碳

MQ-9: 一氧化碳/甲浣

http://www.haoyuelectronics.com/Attachment/MQ-9/MQ9.pdf

常見氣體感測器

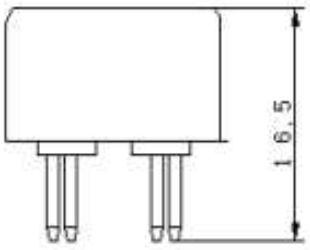
氣體感應器	偵測的氣體
MQ-2	甲烷，丁烷，液化石油氣（LPG），煙。
MQ-3	酒精，乙醇，煙霧
MQ-4	甲烷，CNG 天然氣
MQ-5	天然氣，液化石油氣
MQ-6	液化石油氣（LPG），丁烷氣
MQ-7	一氧化碳
MQ-8	氫氣
MQ-9	一氧化碳，可燃氣體。
MQ131	臭氧
MQ135	空氣質量
MQ136	硫化氫氣體。
MQ137	氨。
MQ138	苯，甲苯，醇，丙酮，丙烷，甲醛氣體。
MQ214	甲烷，天然氣。
MQ216	天然氣，煤氣。
MQ303A	酒精，乙醇，煙霧
MQ306A	液化石油氣（LPG），丁烷氣

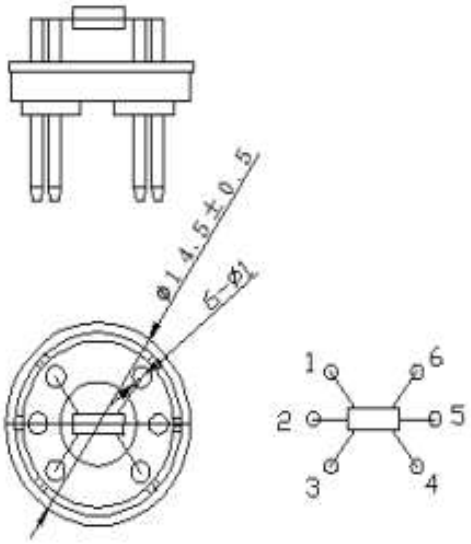


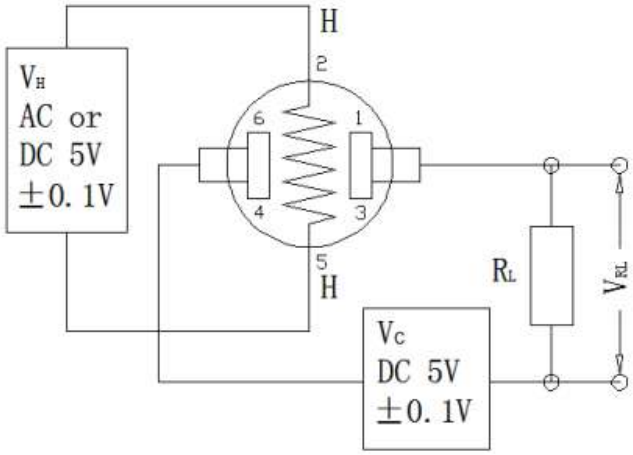
- MQ-3
  - 半導體氣敏元件
    - 酒精檢測濃度：25 ~ 5000 ppm (1ppm = 0.0001%)
    - 氣敏材料：二氧化錫S_nO_2；乾淨空氣中有低電導率
  - 工作原理
    - 感測器電導率隨空氣中酒精濃度增加而變大
    - 將電導率的變化轉化為酒精濃度對應的輸出訊號

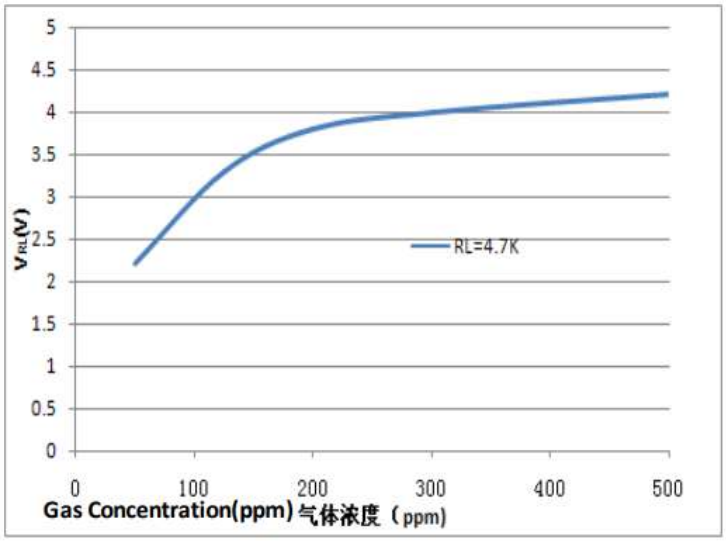
https://cdn.sparkfun.com/datasheets/Sensors/Biometric/MQ-3%20ver1.3%20-%20Manual.pdf

MQ-3基本檢測









MQ-9

Features

- 一氧化碳 / 甲烷 / 液化氣
- 類比輸出 (AO)
- 數位輸出 (DO)

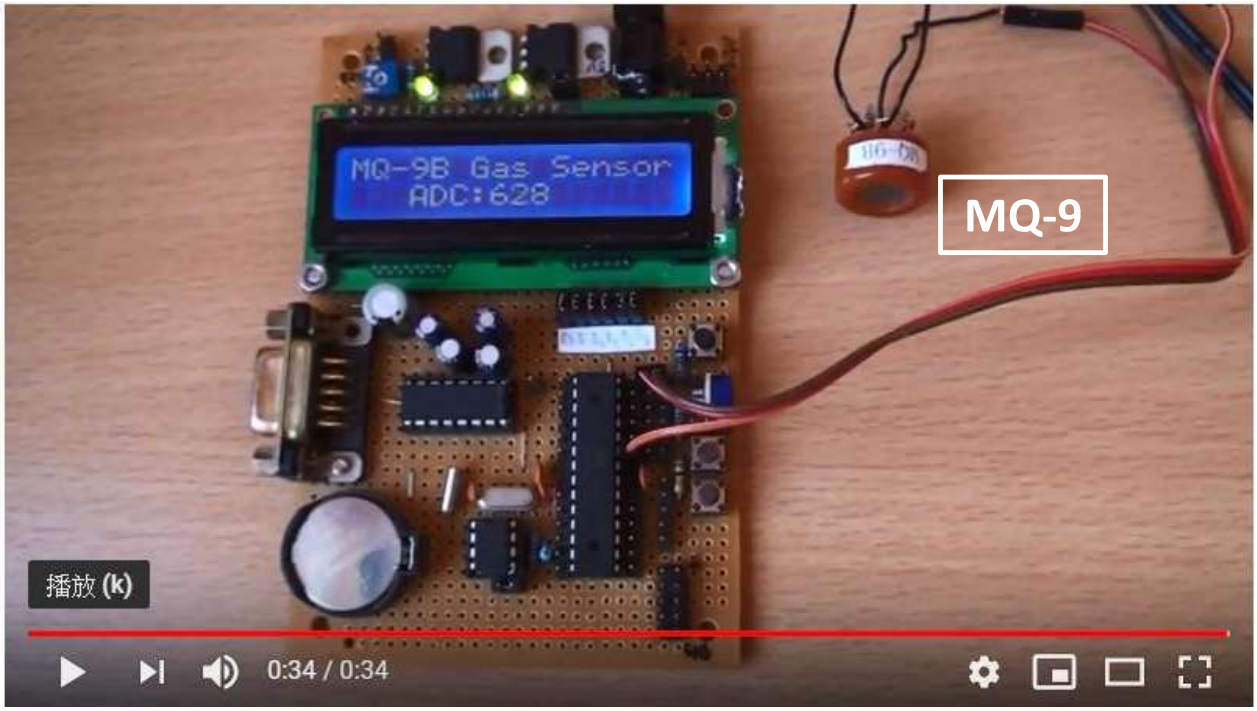
https://www.playrobot.com/gas/1540-mq-9-semiconductor-sensor-cocombustible-gas.html

MQ-9

Features

- Combustible Gas Sensor
- I2C
- Sensing range
  - 10 to 1000ppm
- Communication speed
  - 100KHz ~ 3.4MHz

https://store.ncd.io/product/mq-9-carbon-monoxide-combustible-gas-sensor-adc121c-12-bit-adc-i2c-mini-module/



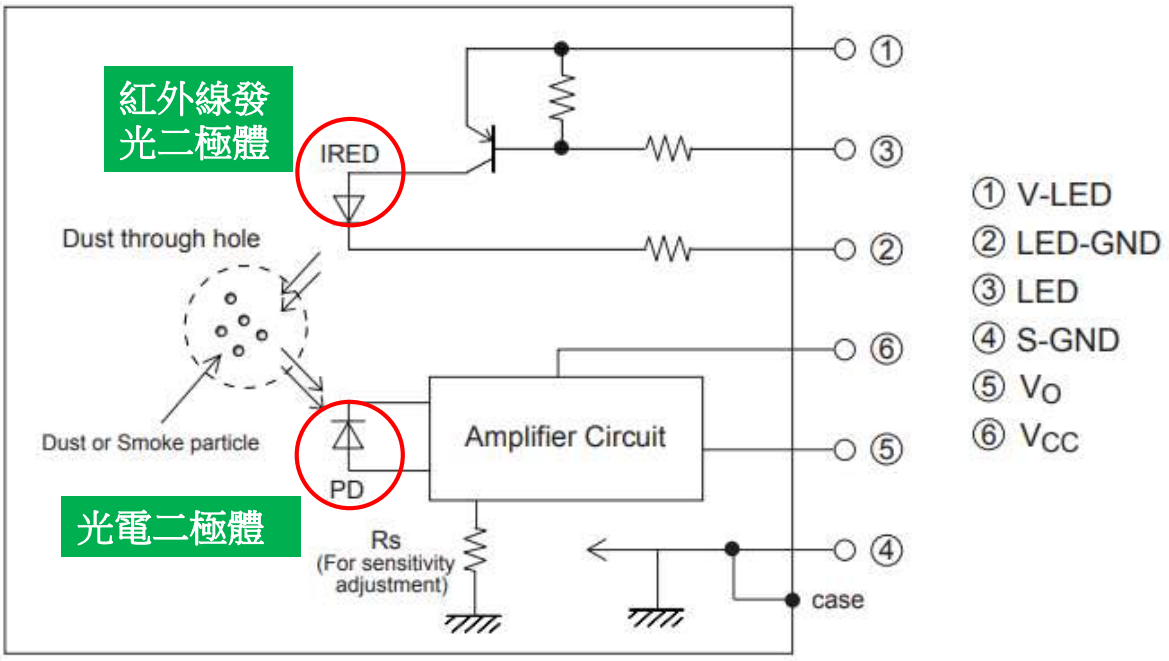
https://www.youtube.com/watch?v=wSQZROau9Vw

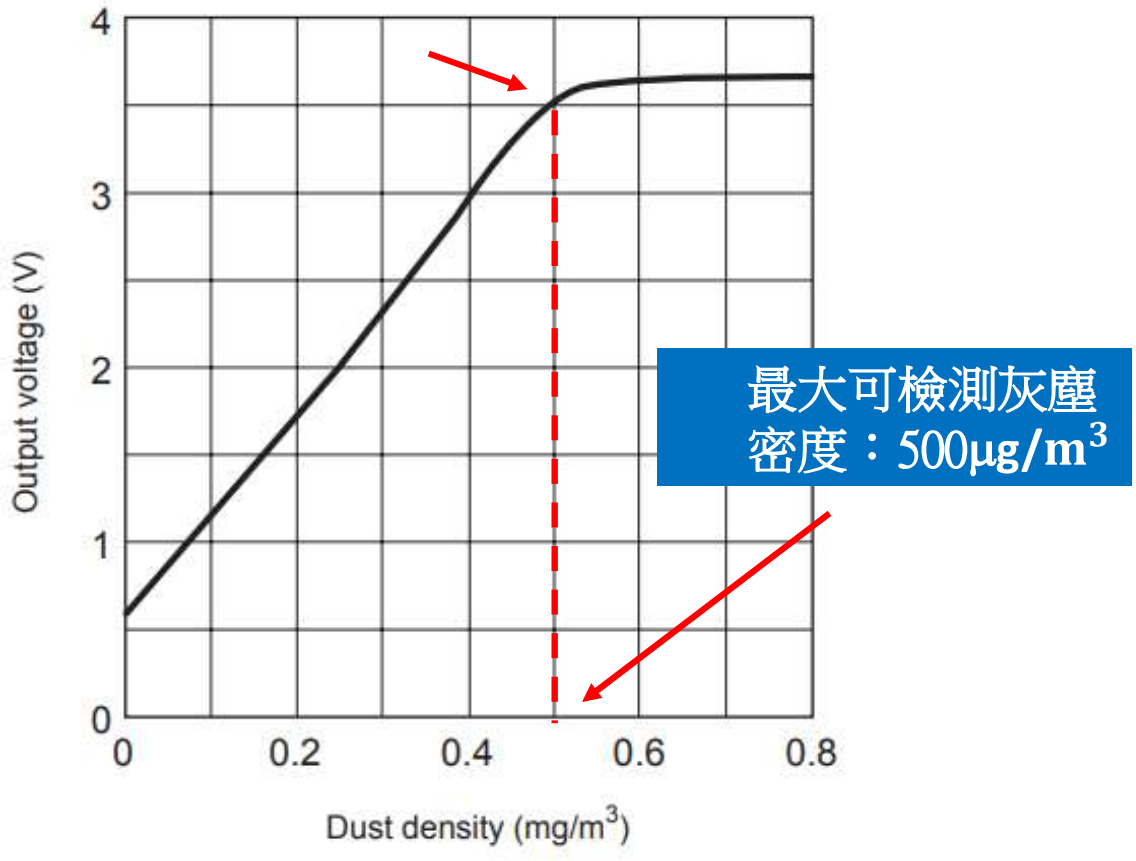
PM Sensor

- PM: **P**articulate **M**atter (懸浮微粒)
  - **PM2.5**: 微粒小於或等於2.5微米 (μm) [$\mu g/m^3$]
    - 易引起支氣管炎、氣喘、心血管疾病

名稱	PM 粒徑 (μm)	說明	影響
總懸浮微粒(TSP)	<100	海灘沙粒	懸浮於空氣中
懸浮微粒	<10	海灘沙粒直徑的 1/10	鼻腔、喉嚨
粗懸浮微粒	2.5~10	頭髮直徑的 1/20	呼吸系統
細懸浮微粒	<2.5	頭髮直徑的 1/28	肺泡、血管

- GP2Y1010AU0F灰塵感測器 (SHARP)



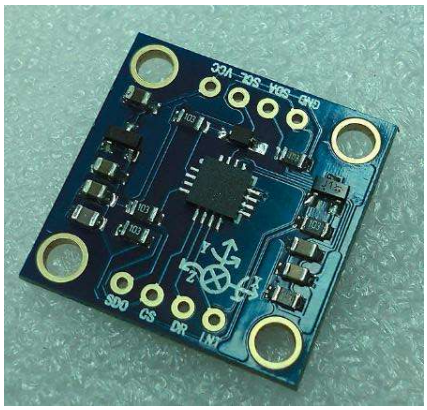


灰塵密度 vs 輸出電壓

運動感測器

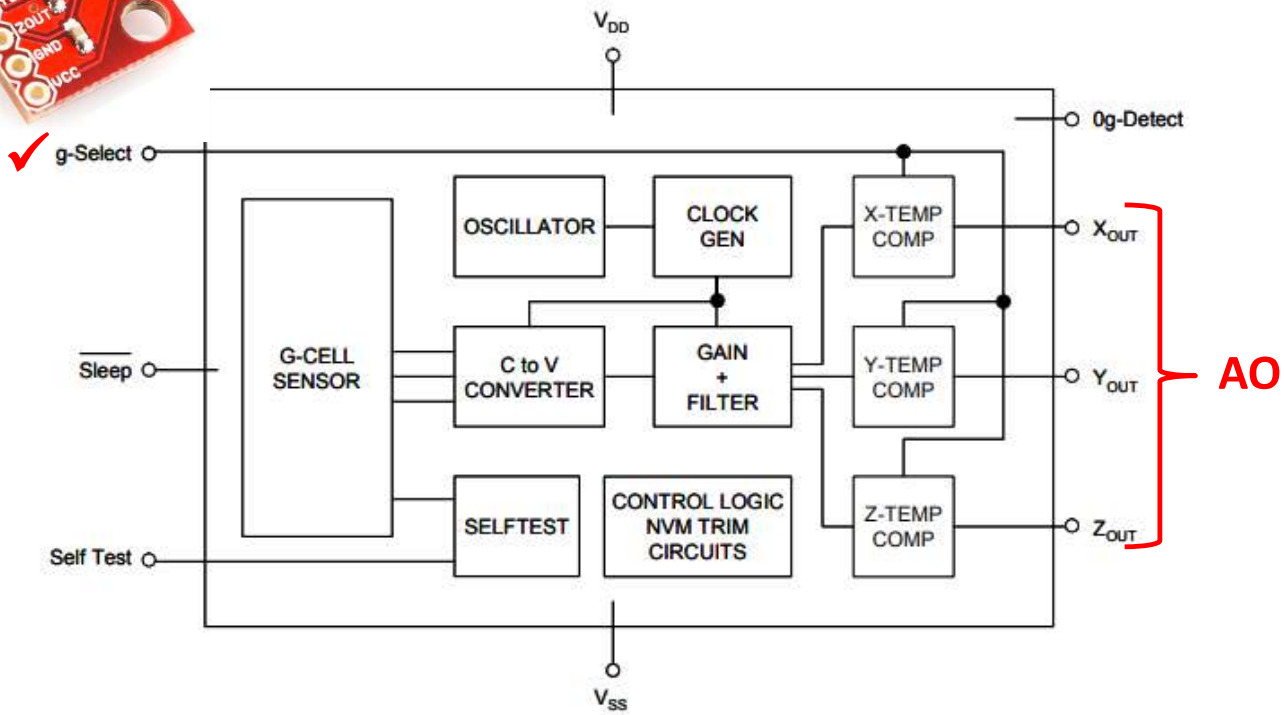
- 常見運動感測器
  - 加速度計 (accelerometer or g-sensor)
  - 陀螺儀 (gyroscope)
  - 電子羅盤 (e-compass)

MMA7361三軸加速度計

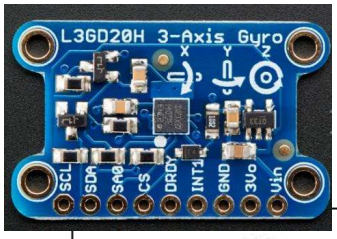


L3G4200陀螺儀

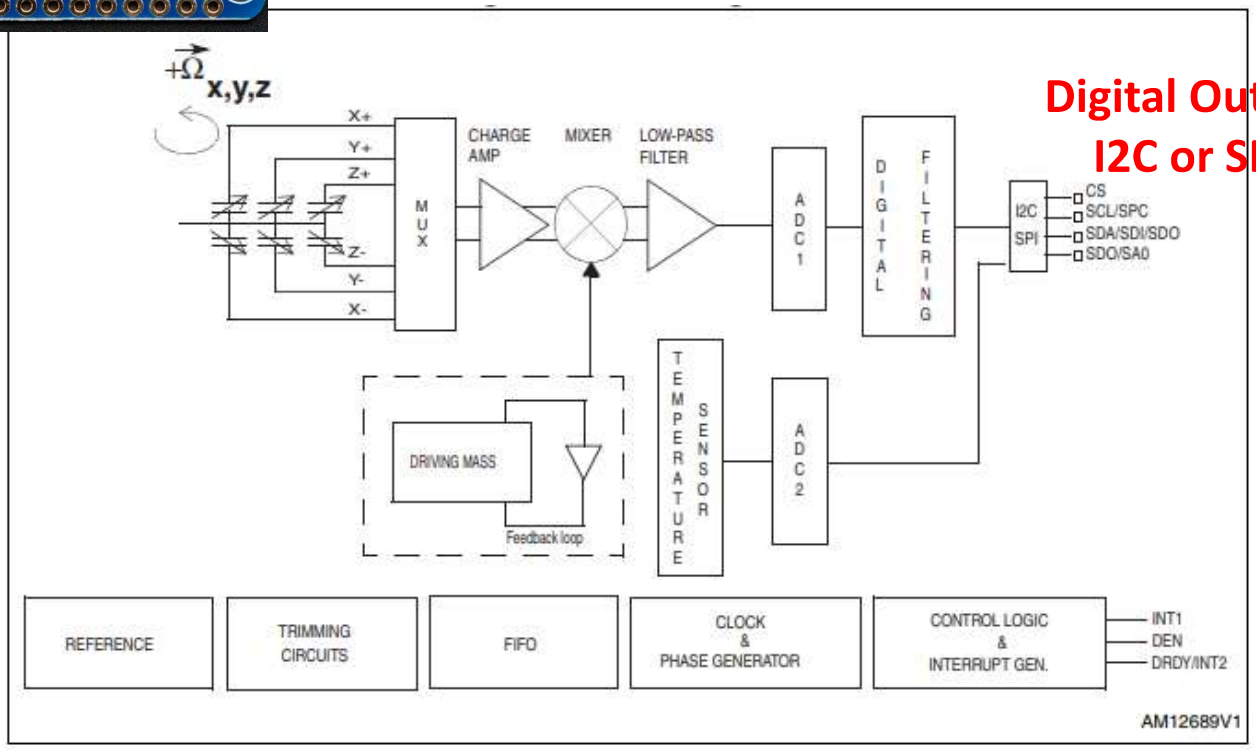
MMA7361



https://www.nxp.com/files-static/sensors/doc/data_sheet/MMA7361L.pdf

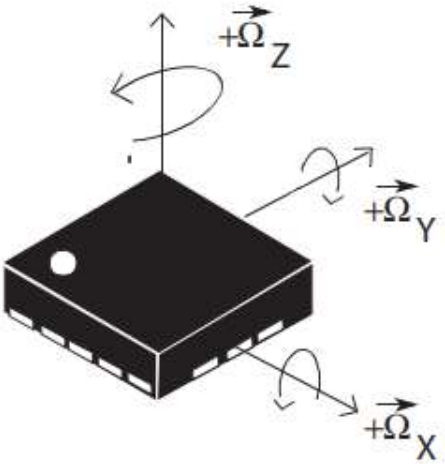


L3GD20H

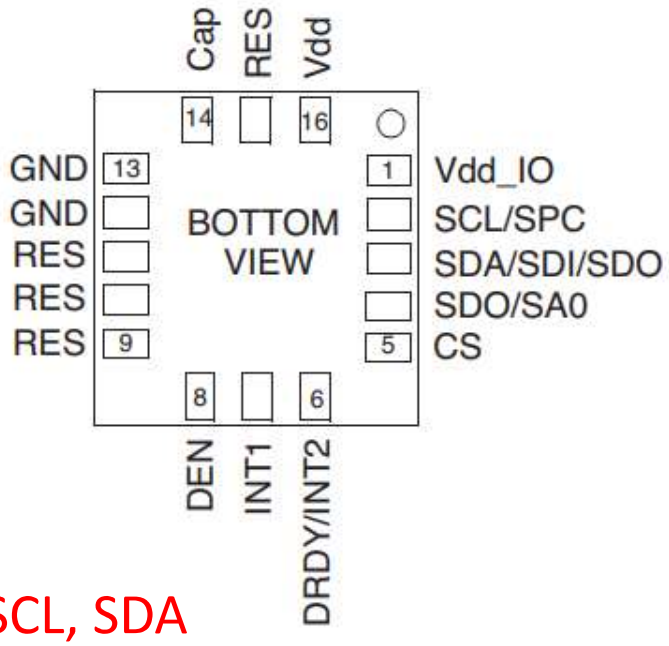


Digital Output
I2C or SPI

https://www.pololu.com/file/0J731/L3GD20H.pdf



(TOP VIEW)
DIRECTIONS OF THE DETECTABLE ANGULAR RATE



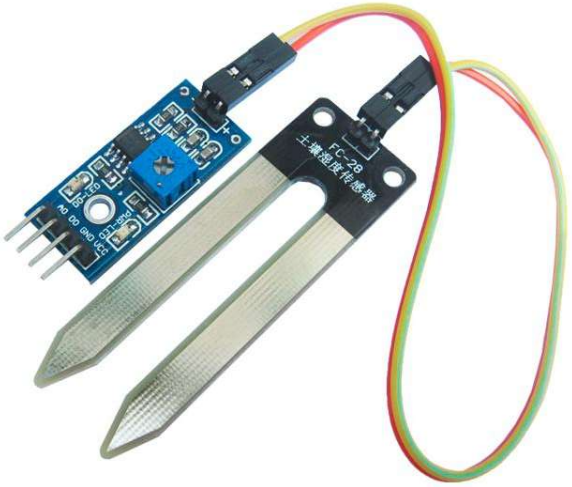
I2C: SCL, SDA
SPI: SPC, SDO
CS: mode selection

- 電子羅盤
  - 量測地磁方向、量測物體靜止時的方向

GY273 電子羅盤

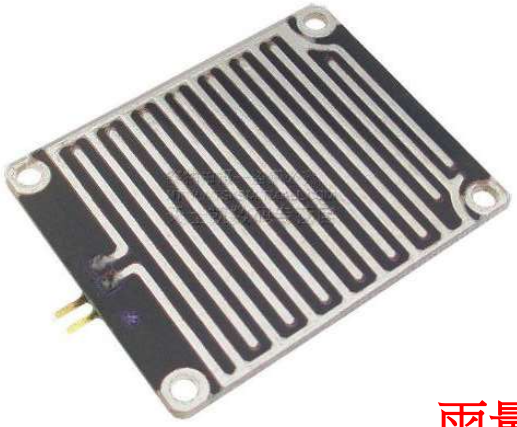
水感測器

- 常見水感測器
  - 土讓濕度
  - 水位
  - 雨量



Moisture Sensor

https://artofcircuits.com/product/fc-28-soil-moisture-sensor-analog-and-digital-outputs



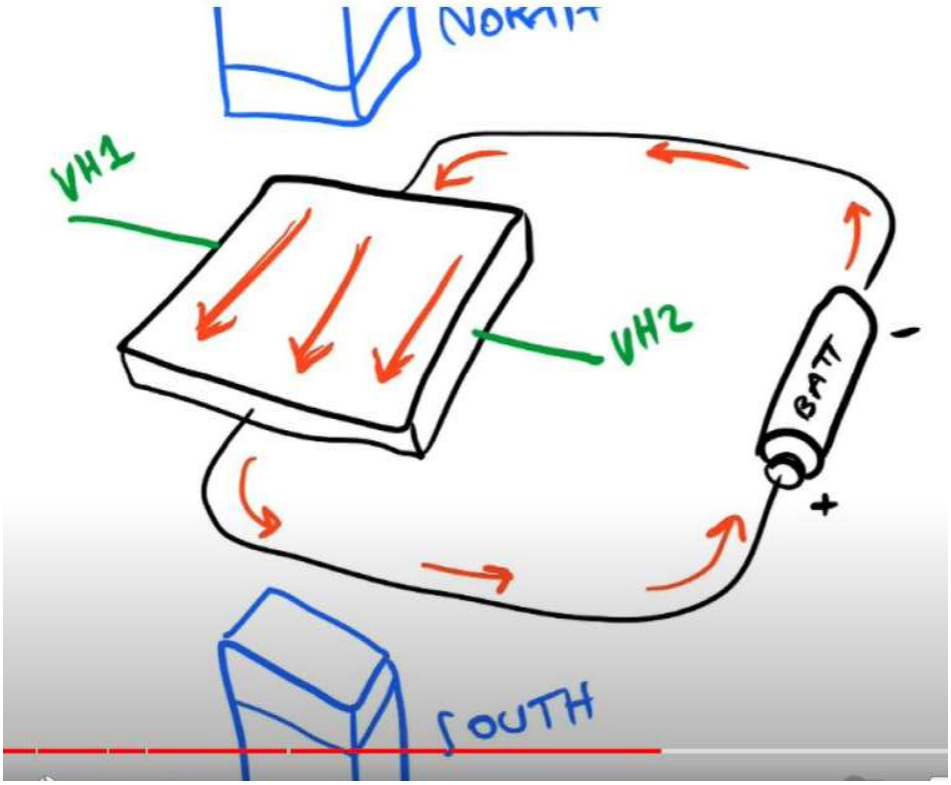
雨量感測器

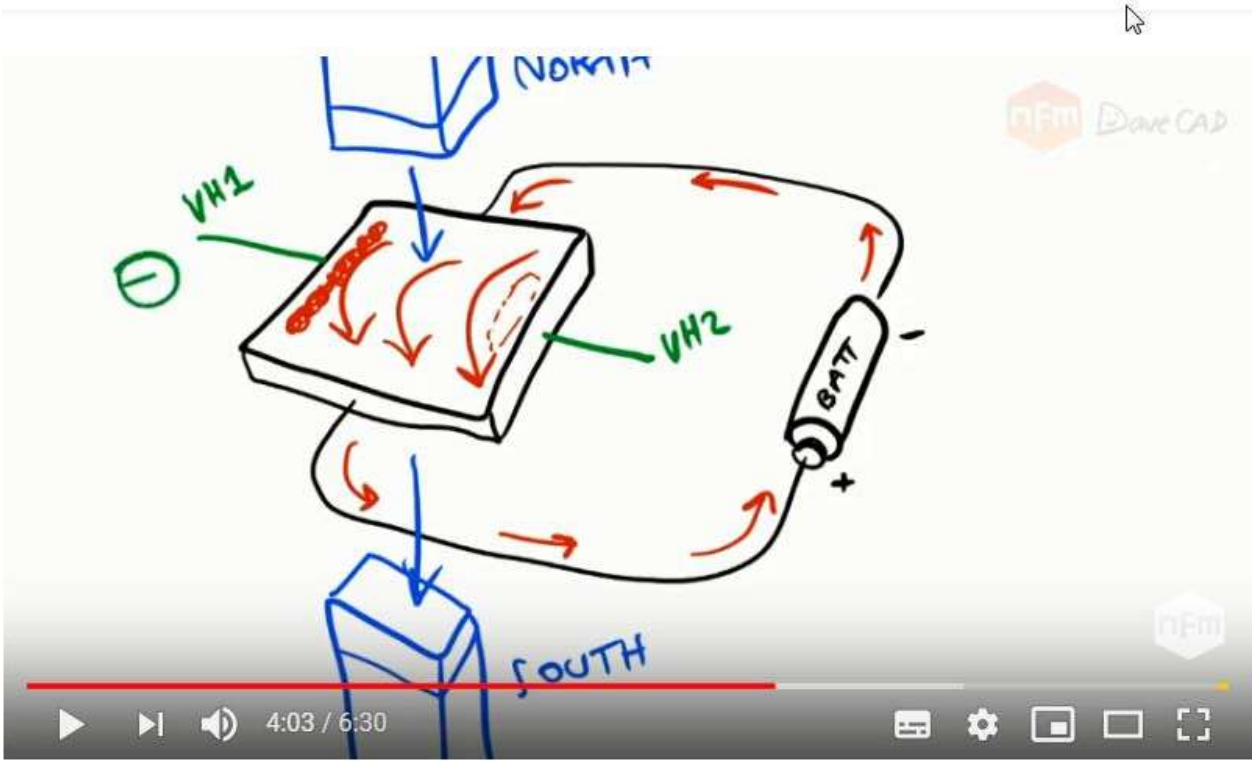
http://www.xintop.com/product_154.html

霍爾感測器

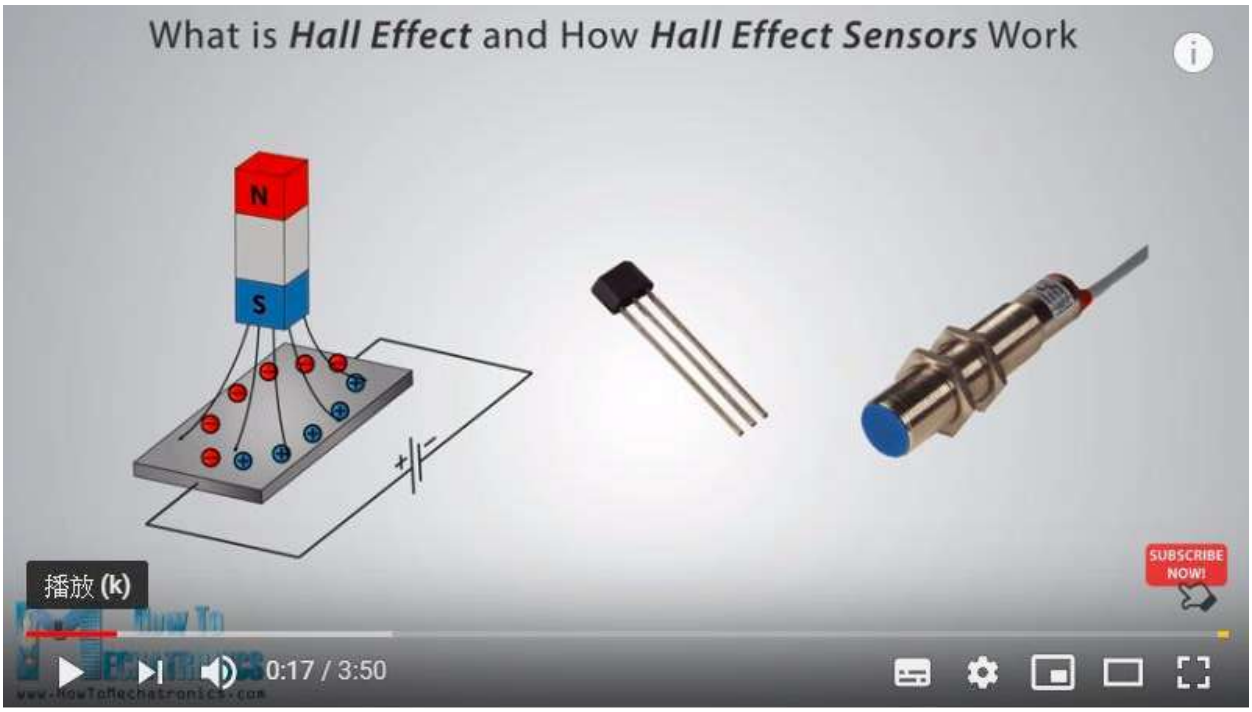
- 霍爾感測器
  - **霍爾效應**(Hall effect)
    - 導體放置在一個磁場內，且有電流通過時，導體內的電荷電子受到勞倫茲力(Lorentz force) 而偏向一邊，繼而產生電壓(霍爾電壓)。
  - 用途廣泛
    - 力矩、拉力、應力、位移、 …

https://www.itsfun.com.tw/%E9%9C%8D%E7%88%BE%E6%84%9F%E6%B8%AC%E5%99%A8/wiki-1831031-5930321

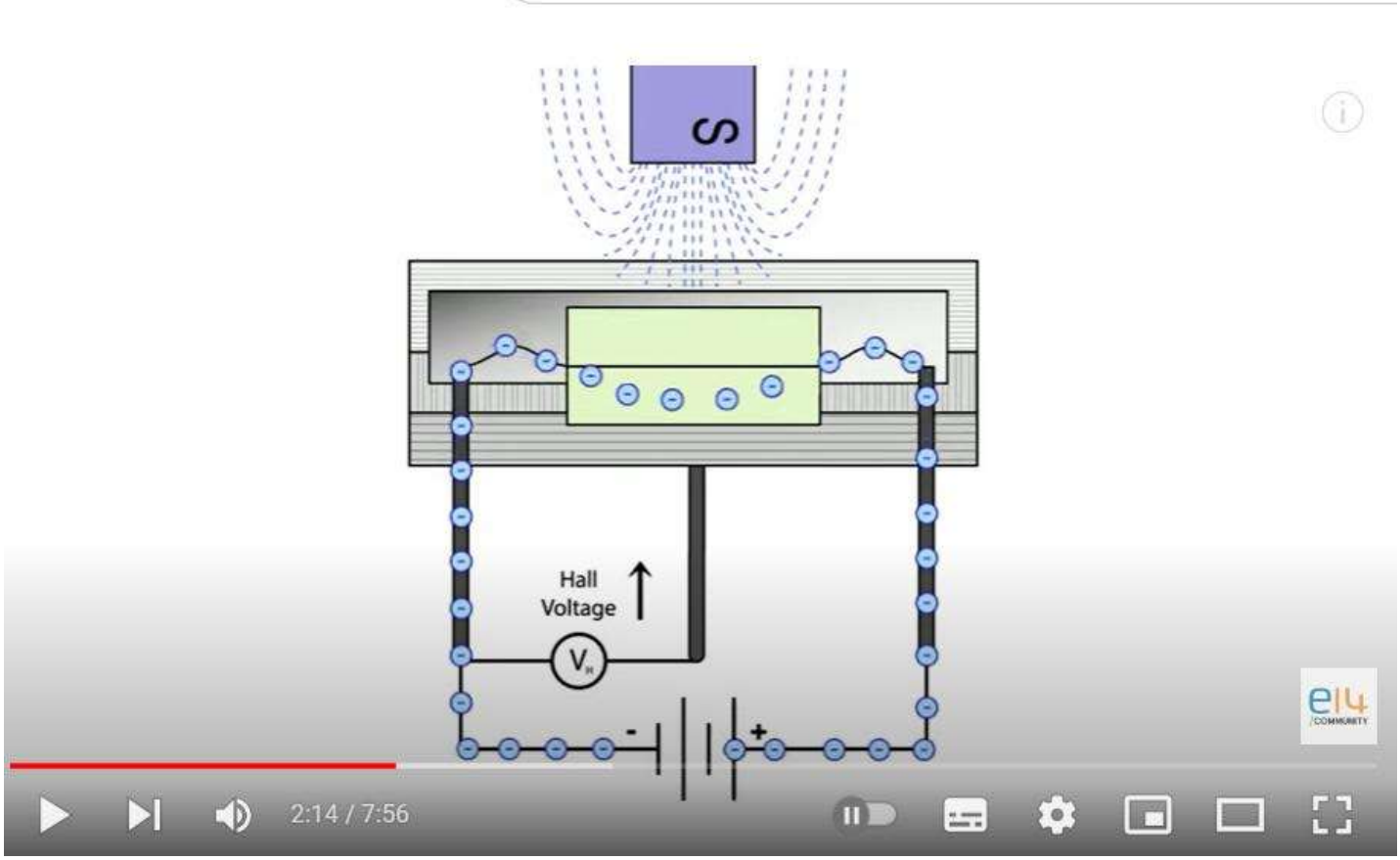




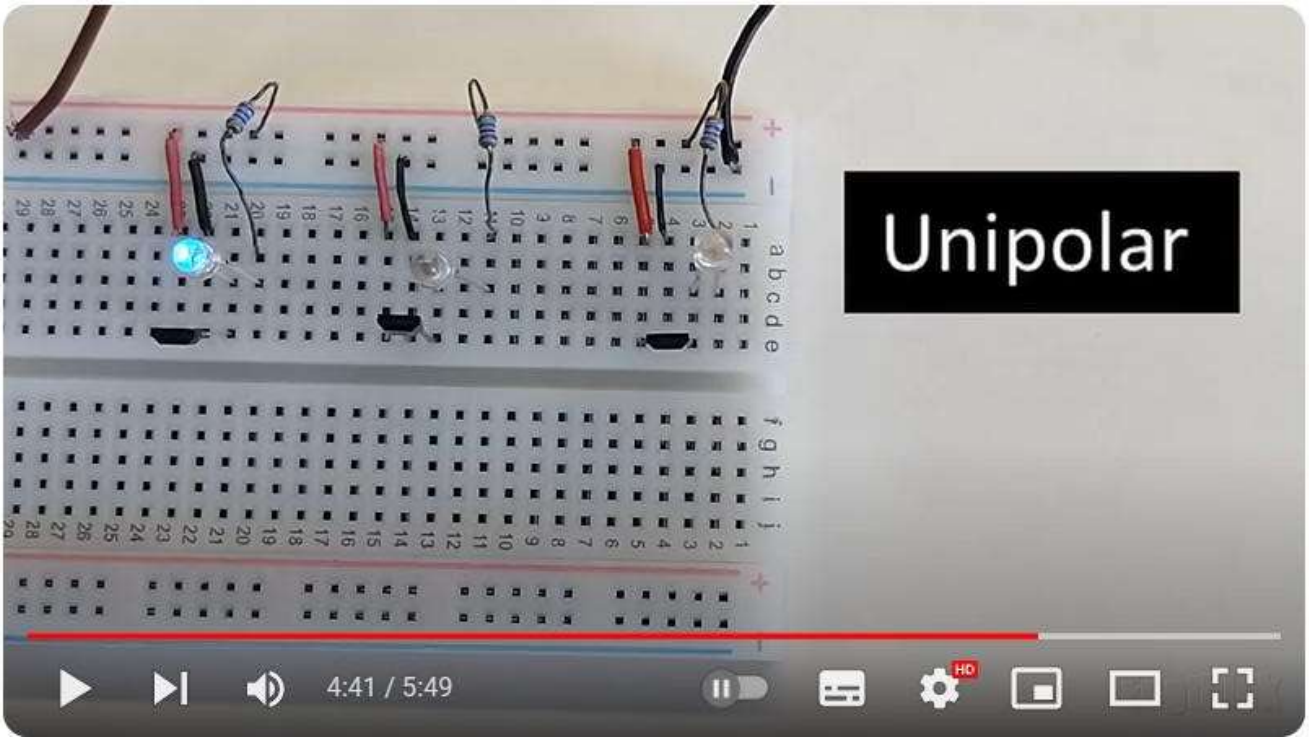
https://www.youtube.com/watch?v=FLWcJQhqsvc



https://www.youtube.com/watch?v=wpAA3qeOYiI



https://www.youtube.com/watch?v=dgyB2-1VDI0&t=431s



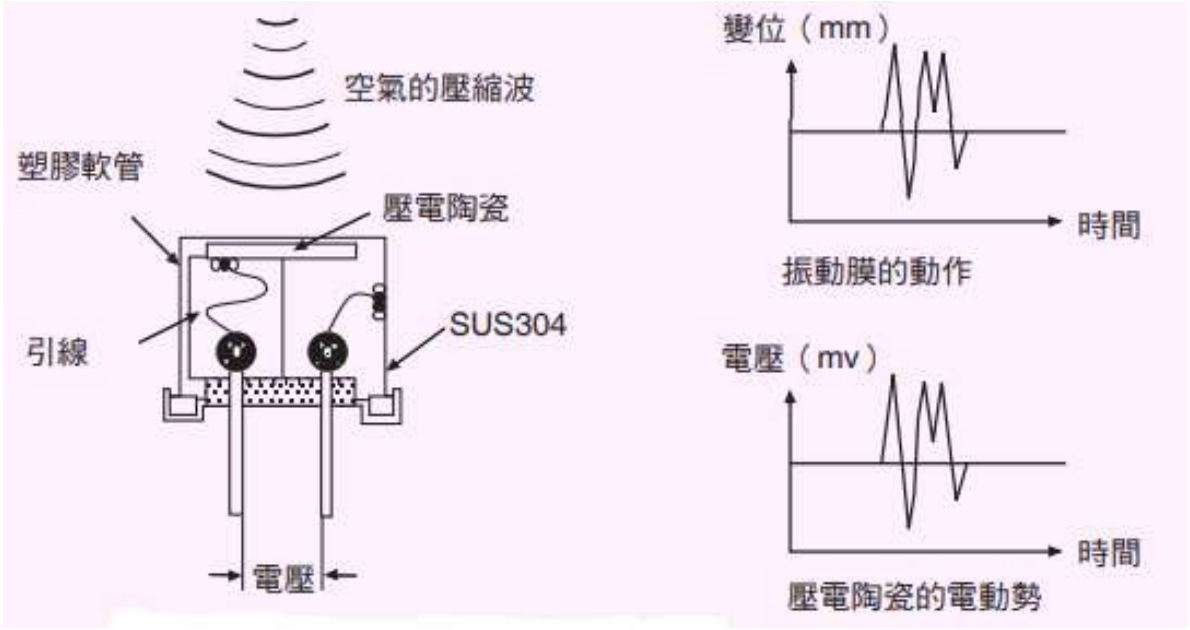
https://youtu.be/VhVj5FF8Qxo?si=qbSROZAtvqZXMnSA

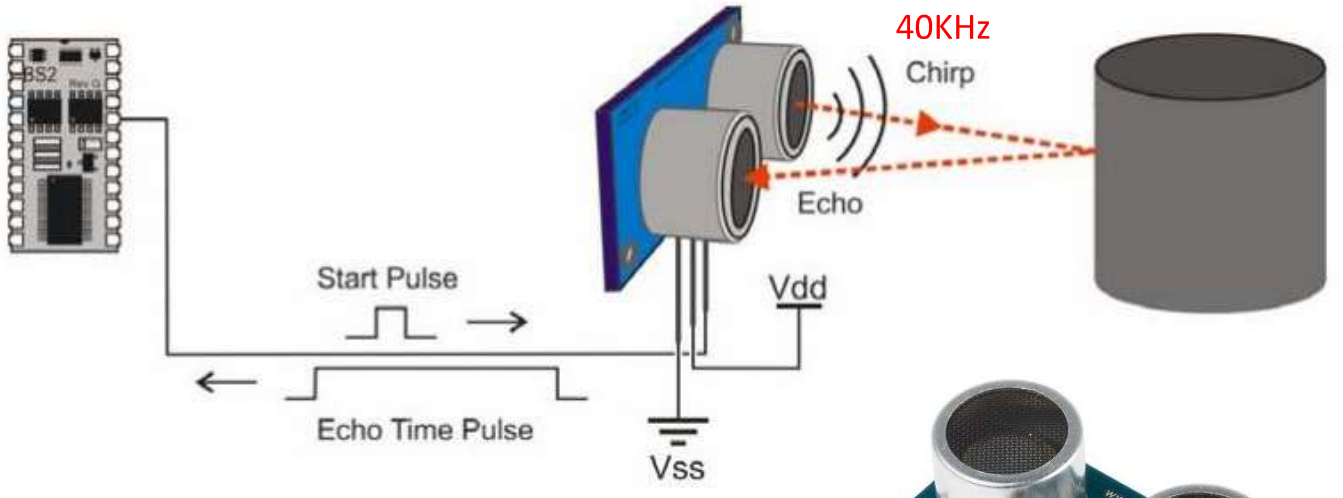
壓力感測器

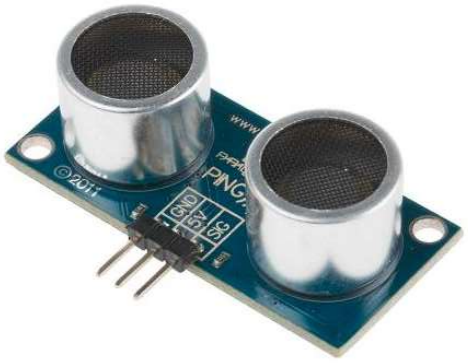
- 壓力感測器

超音波感測器

- 超音波感測器



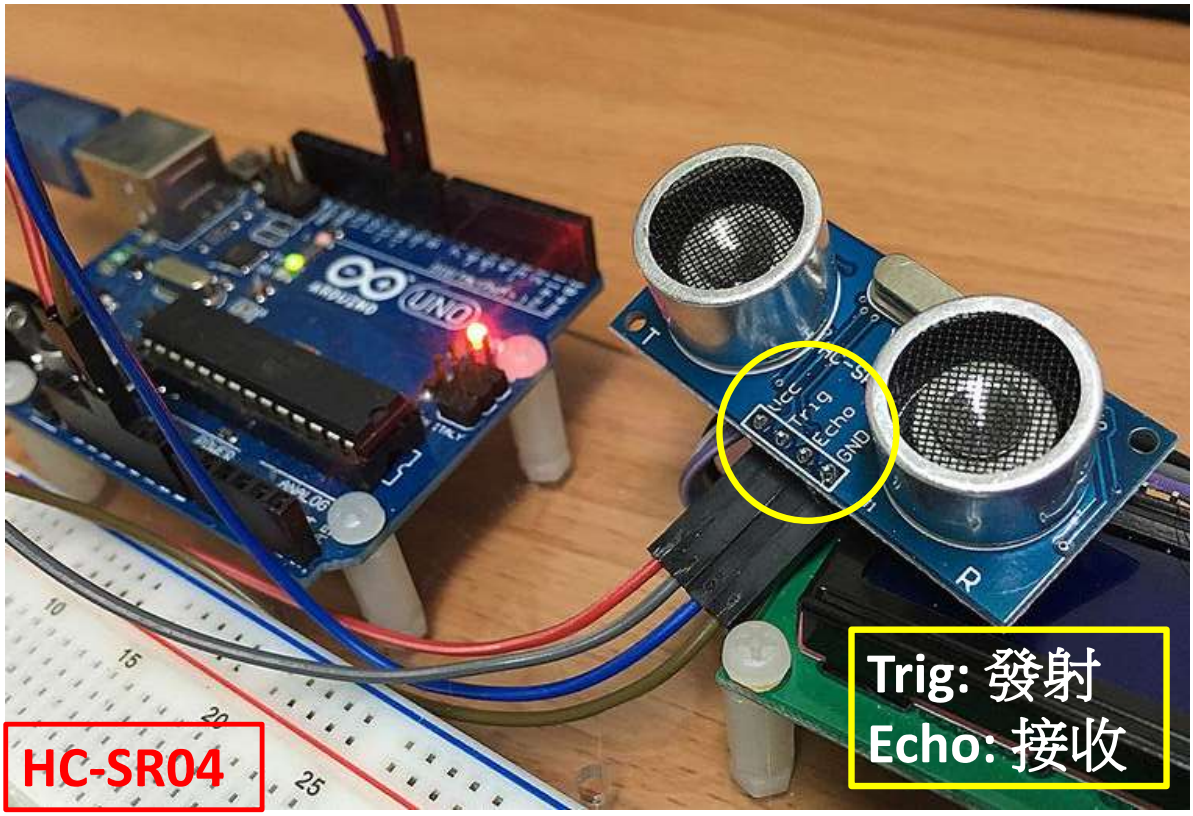


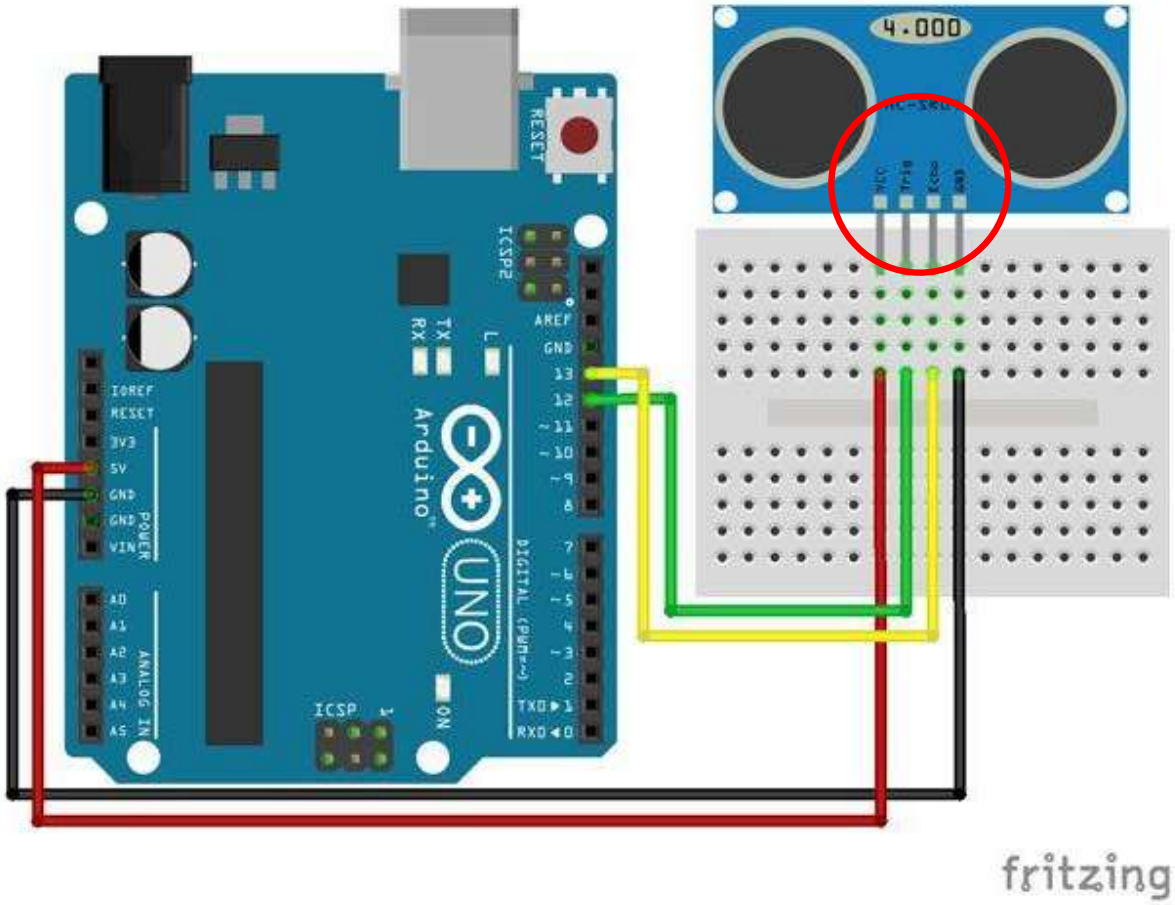


Range: 3cm ~ 3.3m
Chirp: 40KHz

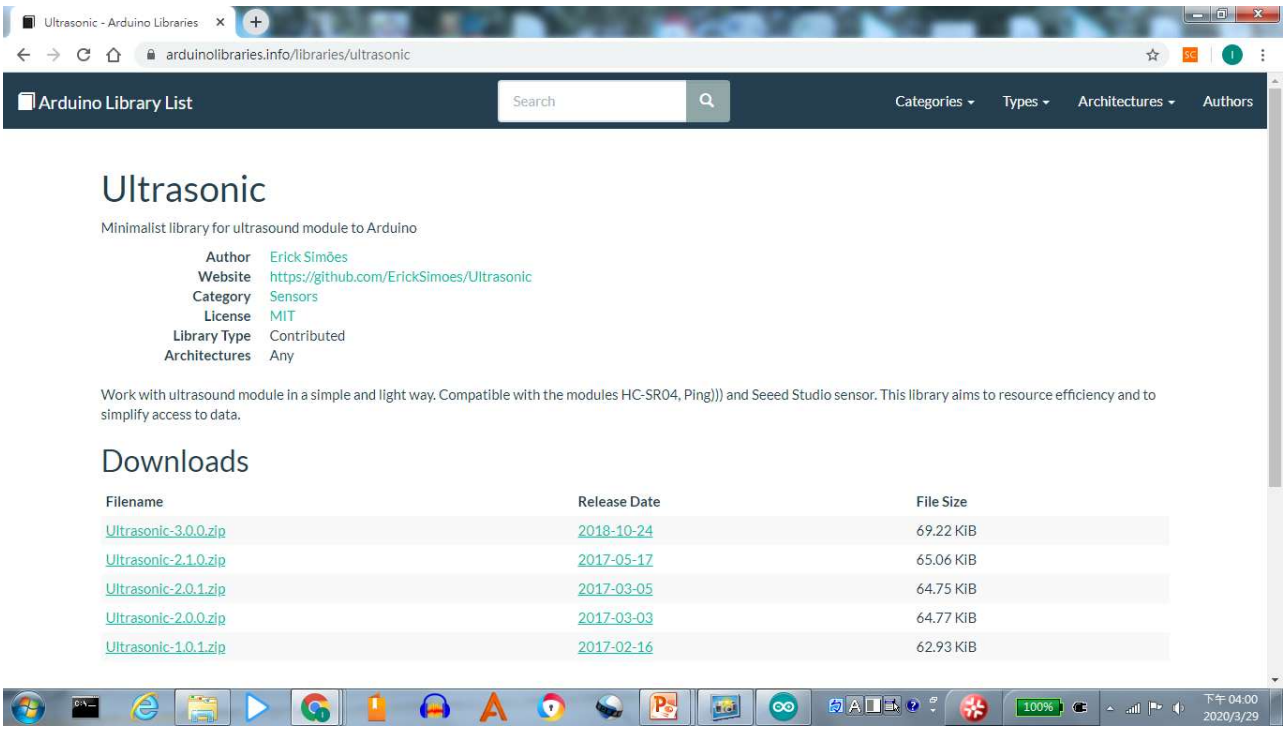
Ping)))

http://users.ece.utexas.edu/~valvano/Datasheets/PingDocs.pdf

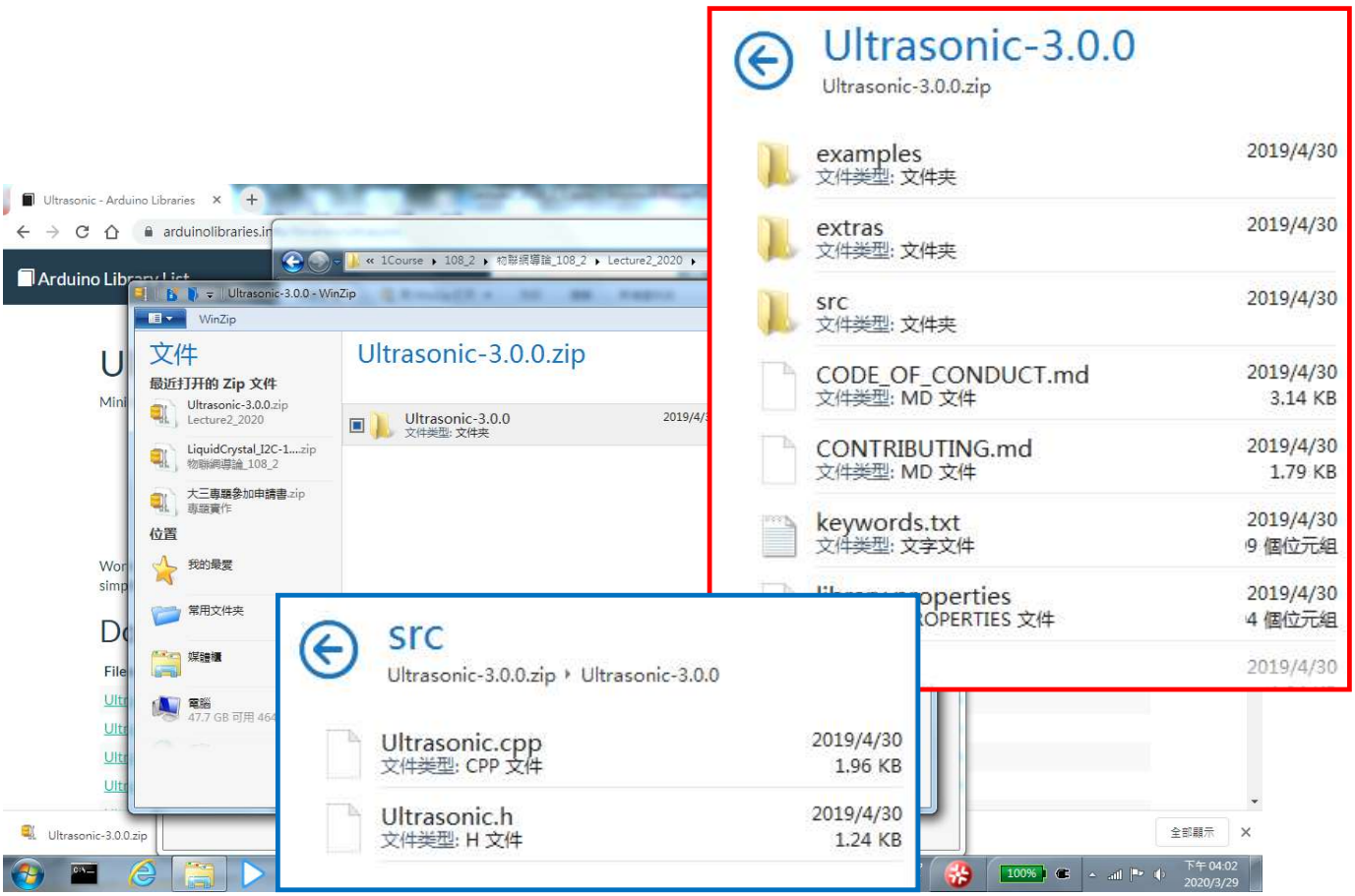

HC-SR04
Trig: 發射
Echo: 接收
VCC
Trig
Echo
GND

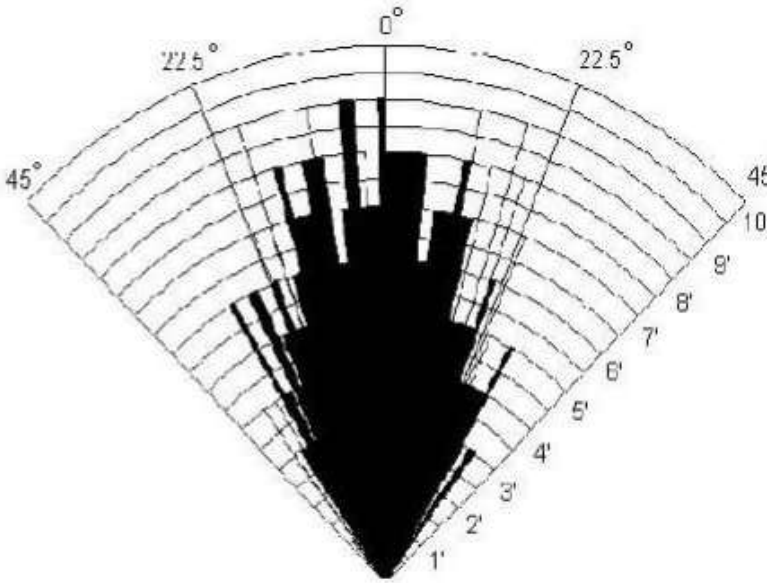

4.000
Arduino
UNO
fritzing

```ino
#include <Ultrasonic.h>

Ultrasonic ultrasonic(12, 13);
int distance;

void setup() {
  Serial.begin(9600);
}

void loop() {

  distance = ultrasonic.read(); //不加參數就是輸出CM，可用read(INC)轉

  Serial.print("Distance in CM: ");
  Serial.println(distance);
  delay(500); //每次間格0.5秒
}
```

https://www.arduinolibraries.info/libraries/ultrasonic



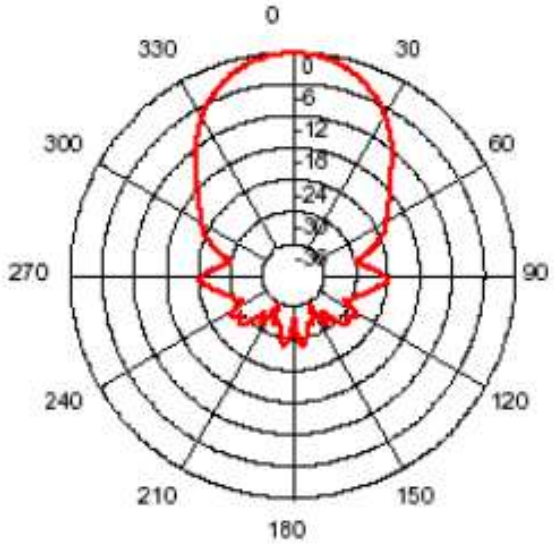


SEN136B5B

Range: 3cm ~ 4m

Best in 30 degree angle

http://fritzing.org/media/fritzing-repo/projects/3/3pi-robot-atmega-328p-and-ultra-sonic-range-measur/other_files/ULTRASONIC%20SEN136B5B.pdf



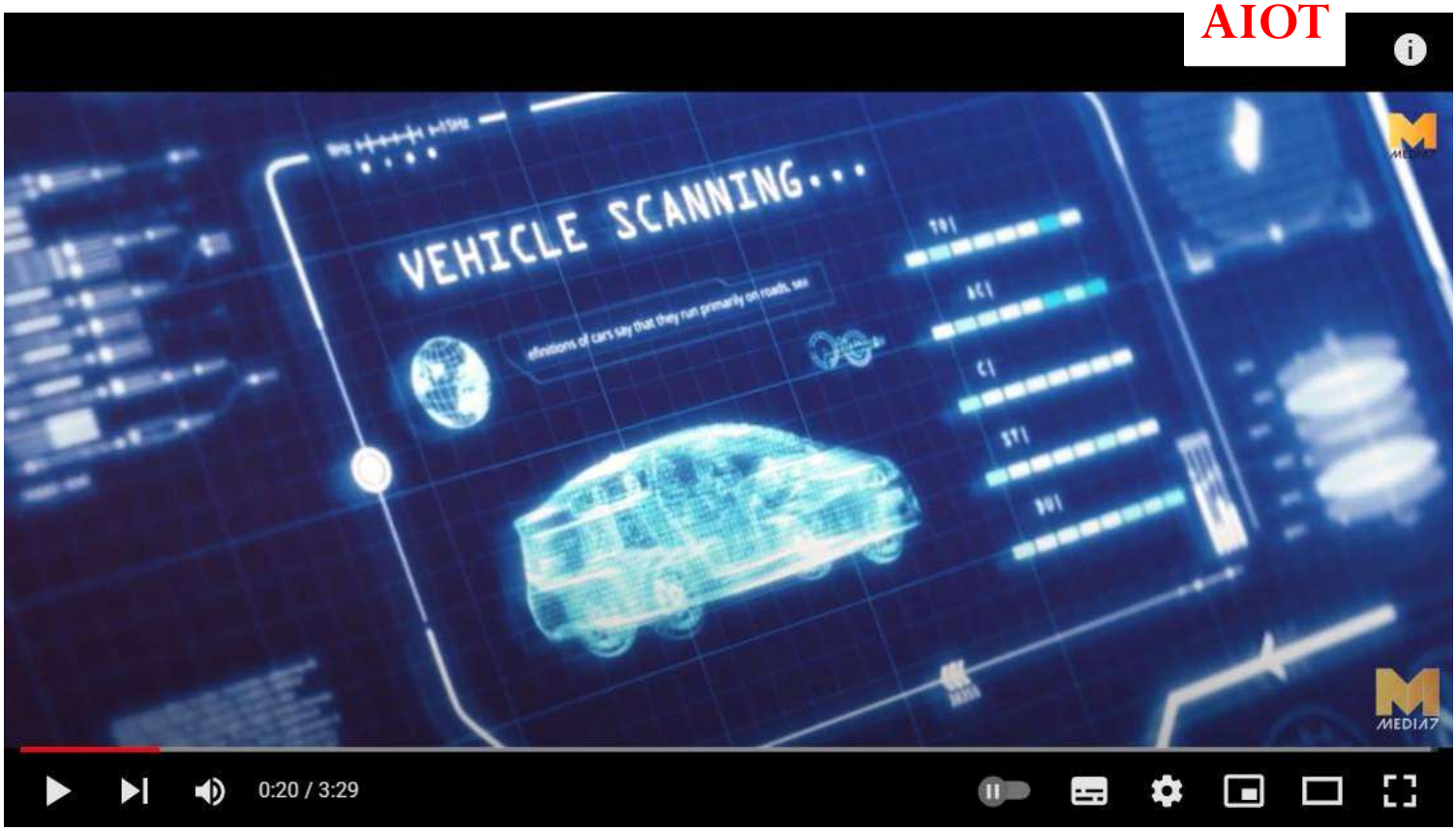
SRF05

Range: 3cm ~ 4m

file:///C:/Users/CGU/Downloads/SRF05%20Technical%20Documentation.pdf

作業

- 觀看p.83影片
  - 請寫下讀後心得
  - 至少300字



https://www.youtube.com/watch?v=D6p5IPepJIM&t=3s

實驗一

- 日期：2024.3.24；09:00~12:00
- 地點：工學大樓(B1) 控制工程實驗室
- 分組：每組3~4人；共10組
- 主題：Arduino & Sensors

1		2			
3		4		9	
5		6		10	
7		8			